MEADOW ECOLOGY AND HYDROLOGY

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The relationship between stream channel morphology, meadow water tables, and soil moisture available for plant growth drive the formation and persistence of many riparian plant communities. Depth to the water table plays an important role in determining soil moisture content through the movement of moisture upward through the soil profile thus providing moisture for plant growth (Jury et.al. 1991). In addition, depth to the water table may influence plant growth, either positively or negatively, when plants are rooted within the water table (Teskey and Hinckley 1977). Stream channels and water tables are intimately linked. In areas where there is considerable recharge of groundwater throughout the catchment, the water table slopes toward rivers that gain water. In more arid areas where there is little or no direct recharge from the catchment the water table lies below the riverbed (Dunne and Leopold 1978). Thus, available soil moisture in many meadows is influenced by stream channel morphology.

The diversion of streamflow for irrigation of riparian meadows is a management process common in many arid areas of the world. Irrigated riparian meadows provide the opportunity to investigate the linkages between the irrigation process, groundwater levels, soil moisture, vegetative biomass, and species composition. Determination of these physical linkages will provide managers with an enhanced understanding of the relationship between stream channels, meadow water tables and the associated riparian plant communities. A study was initiated in 1994 to explore these relationships.

STUDY AREA

The study was conducted in Bear and Silvies valleys located in the south central Grant County, Oregon. Grant County, situated in the Central Blue Mountains of east-central Oregon, lies between 44° and 45° north latitude and 118° and 120° west longitude. Valley floor elevation ranges from 4508 feet to 4680 feet. Climate is characterized by cold winters, moderate summers and low precipitation. The 30 year average summer temperature in Bear Valley is 56.8°F and the mean maximum temperature of 80.0°F occurs during July and August. Average winter temperature is 23.2°F with the mean minimum of 8.4°F occurring in January. Temperature extremes range from 100.0 to -48.0°F. The mean annual precipitation is 13.0 inches and occurs primarily from November through June with the majority of it coming in the form of snow. Mean annual snowfall is 64.0 inches. Silvies Valley does not have a weather station, however, its climate is slightly milder and drier than Bear Valley.

The Silvies River flows from north to south separating Bear and Silvies valleys in half. Bear Valley is further divided by Scotty Creek, a second-order stream, flowing from the west and Bear Creek, a third-order stream, flowing from the east. Both these streams join the Silvies River near the south central portion of Bear Valley. The valley floors are wide and unconstrained with slopes of less than 2 percent.

The valleys soils are classified at the series level as Damon silty clay loam and Silvies silty clay loam. These two soils are quite similar with the Silvies soil exhibiting a slightly higher clay content. They are poorly drained, formed in mixed alluvium with a restrictive layer at 40 to 60 inches. Both are neutral throughout and are mottled below 25 inches. Permeability for both soils is moderately slow, estimated at .6 to 2.0 in/hr. Available water holding capacity is 7.0 to 10 inches and effective rooting depths are 30 to 40 inches.

The SCS Range Site guide for the John Day Land Resource Area (1965) classifies the riparian portion of these valleys as wet and semi-wet mountain meadows. The "original" semi-wet meadow herbaceous component is described as being composed of 25% redtop (*Agrostis alba*), 15% tufted hairgrass (*Deschampsia caespitosa*), 10% each slender wheatgrass (*Agropyron trachycaulum*), sod-forming bluegrasses (*Poa pratensis and P. sandbergii*), and meadow rushes (*Juncus* spp.). Perennial forbs such as cinquefoil (*Potentilla gracilis*), yarrow (*Achillea millefolium*), aster (*Aster occidentalis*), geranium (*Geranium* spp.), buttercup (*Ranunculus* spp.), dandelion (*Taraxacum officinale)*, cow clover (*Trifolium involucratum*), and vetch (*Vicia americana*) make up approximately 10%.

The wet meadow herbaceous plant community has a similar diversity, but a different composition. The "typical" original plant community was 30% tufted hairgrass, 10% each Nevada bluegrass (*Poa nevadensis*), redtop and meadow sedges (*Carex* spp.), 30% other grasses, sedges and rushes. Perennial forbs such as cow clover, cinquefoil, aster, buttercup, strawberry (*Frageria* spp.), avens (*Geum campanulatum*), and groundsel (*Senecio* spp.) add another 10%. Both of these plant communities are tolerant of low temperatures.

METHODS

Plant Community Designation

Initial reconnaissance of the study area indicated that four distinct plant community types representing a gradient from mesic to a hydric moisture regime could be identified on the basis of dominant graminoids. These four plant communities consisted of the following:

1. Wet Carex spp./Deschampsia community dominated by Nebraska sedge (*Carex nebraskensis*), beaked sedge (*Carex rostrata*), Baltic rush (*Juncus balticus*), tufted hairgrass and sloughgrass (*Beckmannia syzigachne*), also present were Kentucky bluegrass, timothy (*Phleum pratensis*), meadow foxtail (*Alopecurus pratensis*), clover, annual and perennial forbs, and other grasses, sedges, and rushes.
2. Moist *Alopecurus pratensis* community strongly dominated by the non-native meadow foxtail, also present were timothy, Kentucky bluegrass, tufted hairgrass, Nebraska sedge, Beaked sedge, Baltic rush, cinquefoil, and other grasses, sedges, rushesand forbs.
3. Moist *Poa pratensis* community dominated by Kentucky bluegrass, also present were timothy, smooth brome (*Bromus inermis*), meadow foxtail, cinquefoil, dandelion, yarrow, clover, sedges, rushes, annual and perennial forbs, other grasses and silver sagebrush (*Artemisia cana*).
4. Dry *Poa pratensis* community dominated by Kentucky bluegrass, also present were smooth brome, junegrass (*Koleria pyramidata*), sandbergs bluegrass, Idaho fescue (*Festuca idahoensis*), squirreltail (*Sitanion hystrix*), wheatgrass, meadow foxtail, pussytoes (*Antennaria* spp.), cinquefoil, yarrow, lupine, strawberry, dandelion, clover, buckwheat (*Eriogonum* spp.), green rabbitbrush (*Chrysothamnus viscidiflorus*), mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*), sedges, rushes, and other forbs and grasses.

Soil Moisture

Soil moisture was measured at two-week intervals in each community type within each of the 12 replication sites from late May through September. Gravitational soil moisture content was determined using the method described by Gardner (1986). One sample from both the 12 and 18 inch depths were collected from each plant community within each site. No soil moisture samples were collected from flooded communities, however, ponded conditions were noted.

Water Table Depth

Water table depth was measured on ten-day intervals in each plant community within each of the 12 replication sites. Five transects consisting of four wells each were placed perpendicular to the creek in each replication. The transects were placed on both sides of the creek in an alternate fashion. Within the transect, the first well was located within three feet of the stream channel. The placement of the remaining three wells was determined by plant community change and/or distance from the previous well on the basis of the following decision process:

1. distance from prior well not to exceed 80 ft.
2. distance from prior well must exceed 25 ft.
3. distance into new plant community to be within the guidelines of 6.5 ft minimum and 25 ft maximum.
4. if a plant community change did not occur within 80 ft of the prior well the next well was placed at 50 ft.

The reference well at the creek was placed at a depth of 50 inches or base flow level of the creek, which ever was greater. Differences in surface elevation from the reference well was determined using standard survey methods. Well depth for the remaining wells was calculated based on the reference well depth plus or minus the change in surface elevation. In 1995 and 1996, depth to creek surface relative to the reference wells was measured concurrently with the wells. Water table depth was monitored every ten days through the irrigation season, every three days from the end of the irrigation period until base level was reached and every ten days after the irrigation transition period. Measurements began in May and ended in late September.

RESULTS AND DISCUSSION

Annual precipitation for 1994 was 8.4 inches, 4.7 inches below the 30 year average and the mean maximum temperature was 1.8°F warmer. Annual precipitation for 1995 (and 1996) was 18.0 inches, 5.0 inches above the 30 year average. Both years (1994 and 1995) are representative of the extreme ends of the precipitation history for Bear and Silvies Valleys. This large variance in precipitation over the two years of the project provided an opportunity to study the response of the vegetative communities to vastly different environmental conditions.

Soil Moisture

Seasonal trends in soil moisture for the four plant community types are illustrated in Figure 1. Korpela (1992) measured soil moisture content in similar plant communities in a non-irrigated riparian area in northeastern Oregon. Results of this study for the moist bluegrass and dry bluegrass communities are quite similar to those from Korpela's moist bluegrass community averaging at least 10% greater soil moisture content throughout the growing season. The soil moisture content within the moist meadow foxtail community was not significantly different than the wet meadow soil moisture early in the season, however a difference did exist by mid-June in 1995. This relationship was not observed in 1994 due to extremely dry conditions.

Water Table Depth

Trends in depth to the water table for the four plant communities are illustrated in Figure 2. Padgett (1982) monitored water table levels in several plant community types in central Oregon and found that the water table level in Kentucky bluegrass communities was generally 20 inches or more below the surface. Korpela (1992) studied water table trends in a dry bluegrass, moist bluegrass and wet meadow communities in northeastern Oregon. He reported water table depths of 20 inches or more for the moist bluegrass community and 40 inches or more for the dry bluegrass during the growing season. Water table depths for these communities within this study area were similar to Korpelas' during the 1994 growing season but were generally 8 inches closer to the surface during the 1995 growing season. This result can be attributed to the increased water available for irrigation during 1995. Padgett (1982) found that the water table in wet meadows dominated by *Carex rostrata* or C. *aquatilis* was at or near the ground surface until mid-summer, similar to trends for wet meadow communities within this study.

Ponded conditions occurred at 26% of the 46 wet community wells in mid-June 1994 and 67% had a water table ≤ 12 inches below the soil surface. The moist meadow foxtail community had a water table within 12 inches of the surface at 17% of the well sites in mid-June

1994. In 1995, ponding occurred at 50% of the wet meadow and 6% of the moist meadow foxtail well sites in late May 1995. By mid-June ponding had ceased in the moist meadow foxtail community while 41% of the wet meadow well sites were ponded. Ponding continued through late July at 10% of the wet community sites. The water table was within 12 inches of the ground surface during mid-June 1995 for 91% of the sites located in a wet meadow community and 63% of the well sites within the moist meadow foxtail community. By mid-July only 8% of the moist meadow foxtail sites had a water table $\leq$ 12 inches below the surface while the wet community had 63%.

Table 1. Average forage production on a dry-matter basis by plant community and year (lb/ac).

	1994	1995
Moist Bluegrass	2291	2807
Moist Meadow Foxtail	5298	6644
Wet Meadow	4697	5879
Dry Bluegrass	817	1036

Aboveground biomass

Aboveground biomass for the four community types found within the study area are illustrated in Table 1. All four plant communities appeared to respond to the above normal precipitation in 1995 through increased production. The moist bluegrass community produced an average of 2291 lb/ac in 1994 and 2807 lb/ac in 1995, significantly less than the moist meadow foxtail community and the wet community. The meadow foxtail community produced an average of 5298 lb/ac in 1994 and 6485 lb/ac in 1995 while the wet community averaged 4697 and 6000 lb/ac, respectively.

Meadow Water Table and Creek Surface

Meadow water table profiles for all sites were determined by adjusting the absolute water table depth at each well for ground surface elevation change relative to the reference well located at creekside.

Meadow water tables followed the drop in creek level throughout the summer (Figure 3). Water table measurements indicate the creek switched from being a stream which gained water from the shallow water table (effluent) to one which lost water to the water table (influent) by mid-August in 1996. However, the Bear Creek sites remained effluent through September in 1995.

Soil Moisture - Water Table Depth

Soil moisture and water table depth data from both years were combined and analyzed using simple linear regression. A strong linear predictive relationship exists between depth to water table and soil moisture content as illustrated by Figure 4.

Table 2. Average mid-June soil moisture content (%) for the moist bluegrass and dry bluegrass communities at 30 and 45 cm. depth. 1 inch = 2.5 cm.

	Moist Bluegrass	Dry Bluegrass
1994: 30 cm	42	29
1995: 30 cm	51	34
1994: 45 cm	46	32
1995: 45 cm	58	36

Vegetative States and Transition Zones

Soil moisture content during the growing season is pivotal in the determination of plant communities. The average soil moisture content in mid-June for the four plant communities contained within this study area are presented in Tables 2 and 3.

The threshold (boundary) between the moist bluegrass community and the dry bluegrass community is quite stark. The ranges in average soil moisture for these two plant communities do not overlap. Average soil moisture content in the moist bluegrass community during the dry year is 8% greater than the average soil moisture content in the dry bluegrass community during the wet year (Table 2). The threshold between the moist bluegrass community and the dry bluegrass community lies near 41 percent soil moisture in mid-June. The extreme differences in precipitation during the two years of the study is evident in the soil moisture content within plant communities each year.

Table 3. Average mid-June soil moisture content (%) for the moist meadow foxtail and moist bluegrass communities at 30 and 45 cm depth. 1 inch = 2.5 cm.

	Moist Meadow Foxtail	Moist Bluegrass
1994: 30 cm	51	42
1995: 30 cm	66	51
1994: 45 cm	58	46
1995: 45 cm	81	58

The threshold between the moist meadow foxtail and moist bluegrass community is not quite as stark. During the dry year the soil moisture content within the moist meadow foxtail community averaged 51% and during the wet year the moist bluegrass community averaged 51% (Table 3). Thus, the threshold appears to lie at 51% soil moisture during the growing season. Anaerobic conditions within the rooting zone during the growing season is also an important component in determination of a threshold between these two communities. The water table depth in mid-June 1995 was less than 12 inches below ground surface at 11% of the well sites located in the moist bluegrass community in contrast to 63% of the well sites located within the moist meadow foxtail community. In mid-June 1994, 17% of the well sites located within the moist meadow foxtail community exhibited water table levels within 12 inches of the surface whereas 0% of the wells located within the moist bluegrass community showed a water table less than 12 inches below the surface. Due to the difficulty in determining soil moisture content of saturated soils, the average soil moisture content for the moist meadow foxtail community may be understated. It is conceivable that the threshold between the moist bluegrass community and the moist meadow foxtail community is slightly greater than 51% soil moisture content during the growing season.

Table 4. Average mid-June water table depth (cm) for the wet meadow, moist meadow foxtail, moist bluegrass, and dry bluegrass communities. 1 inch = 2.5 cm.

	1994	1995
Wet Meadow	22	10
Moist Meadow Foxtail	48	24
Moist Bluegrass	69	50
Dry Bluegrass	103	91

The threshold between the wet community and the moist meadow foxtail community cannot be determined by soil moisture content due to the difficulty associated with determination of soil moisture content for saturated soils, however, depth to water table during the growing season provides the necessary information. Average water table depths for the wet meadow community and the moist meadow foxtail community during mid-June are presented in Table 4. During the dry year the average water table depth was 8.6 inches in the wet community and during the wet year the average water table depth for the moist meadow foxtail community was 9.5 inches. The threshold between the wet community and the moist meadow foxtail community appears to occur at a water table depth of 9.0 inches during the growing season.

CONCLUSIONS

The results of this study indicated that soil moisture and/or depth to the water table was the predominant variable in determination of the plant community. The plant communities contained within this study area displayed definite preferences with respect to soil moisture content and/or water table depth during the growing season. Vegetative states and transition zones between plant communities can be defined on the basis of the average range in soil moisture and/or water table depth during the growing season. The relationship between water table and soil moisture can be used to determine the impact of a permanent water table change on the existing plant community. The tight link between meadow water tables and creek surface combined with this information provides a management a tool which can be used to predict riparian plant community response to stream downcutting, widening, or restoration.

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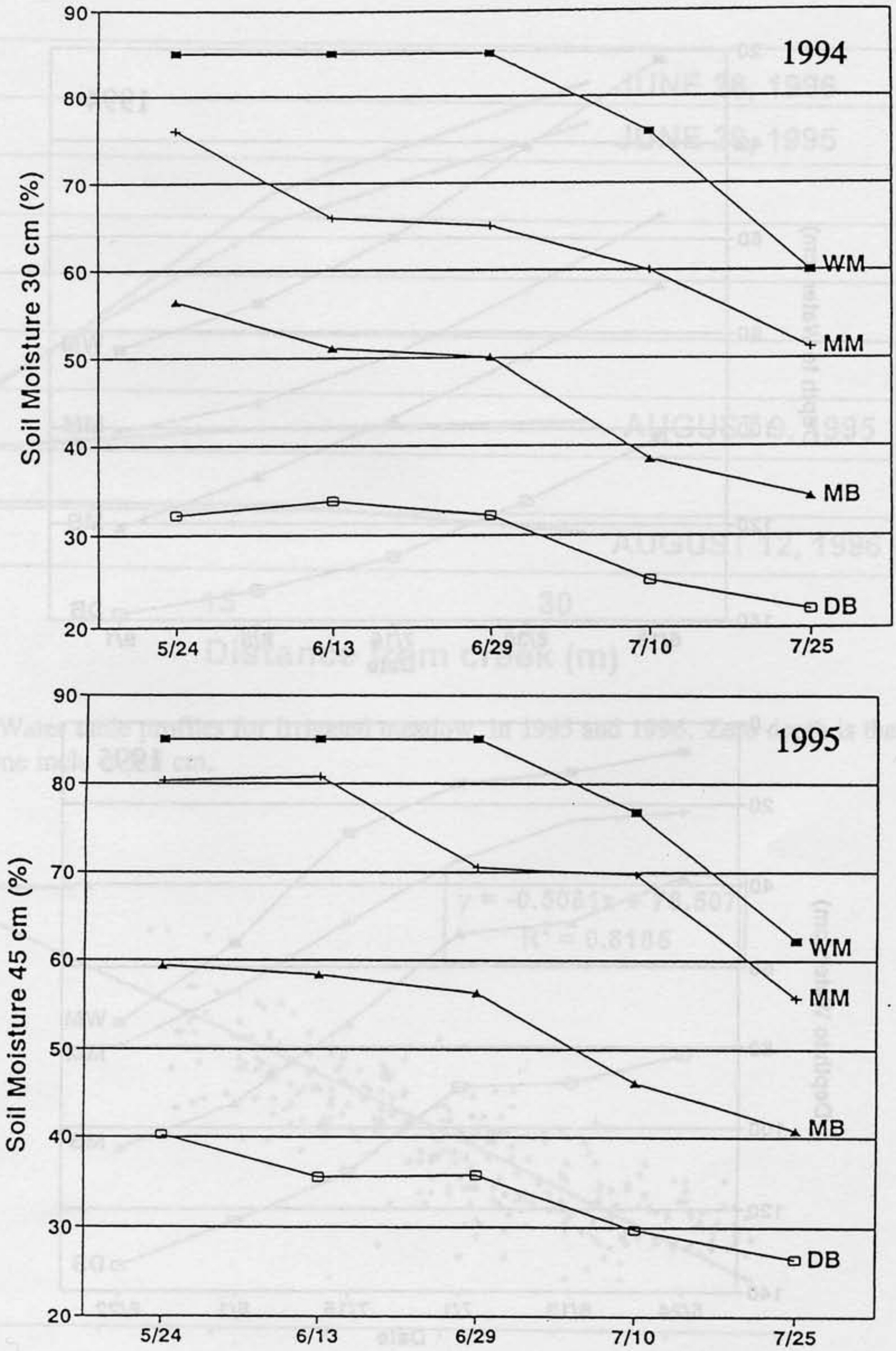

Figure 1. Seasonal trends in average soil moisture content at 30 cm (12 inch) depth during 1994 and 45 cm (18 inch) depth during 1995 within 4 plant communities. Communities were: moist bluegrass (MB), dry bluegrass (DB), moist meadow foxtail (MM), and wet meadow (WM)

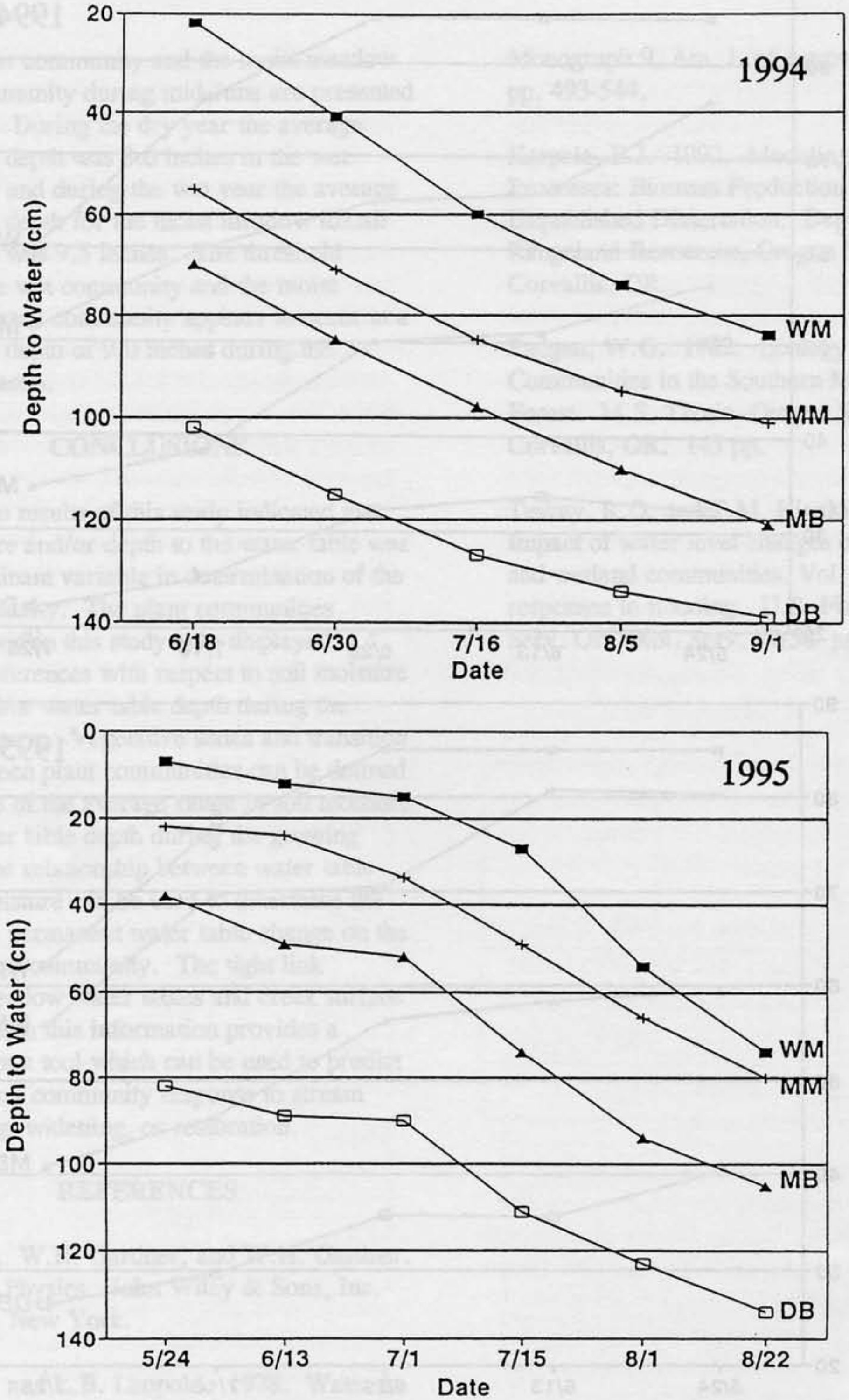

Figure 2. Seasonal trends in average depth to the water table during 1994 and 1995 within 4 plant communities. Communities were: moist bluegrass (MB), dry bluegrass (DB), moist meadow foxtail (MM), and wet meadow (WM). One inch = 2.5 cm.

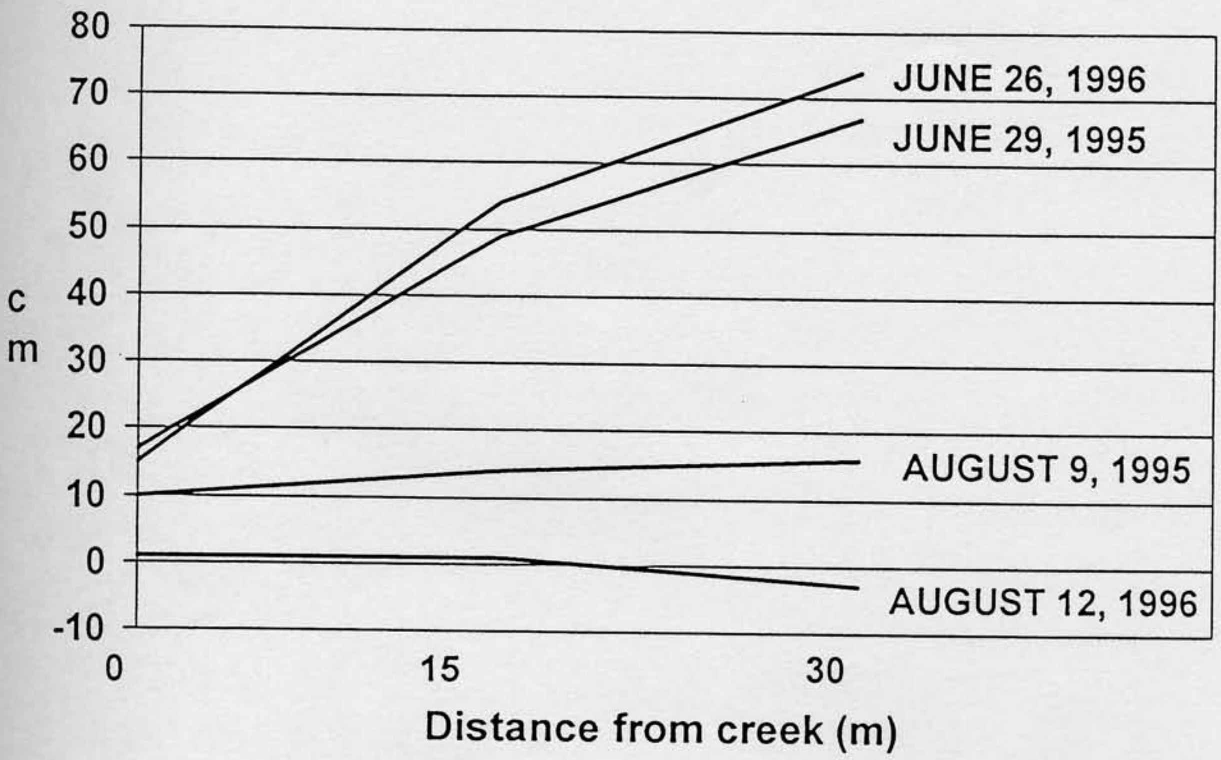

Figure 3. Water table profiles for irrigated meadow in 1995 and 1996. Zero depth is the soil surface. One inch = 2.5 cm.

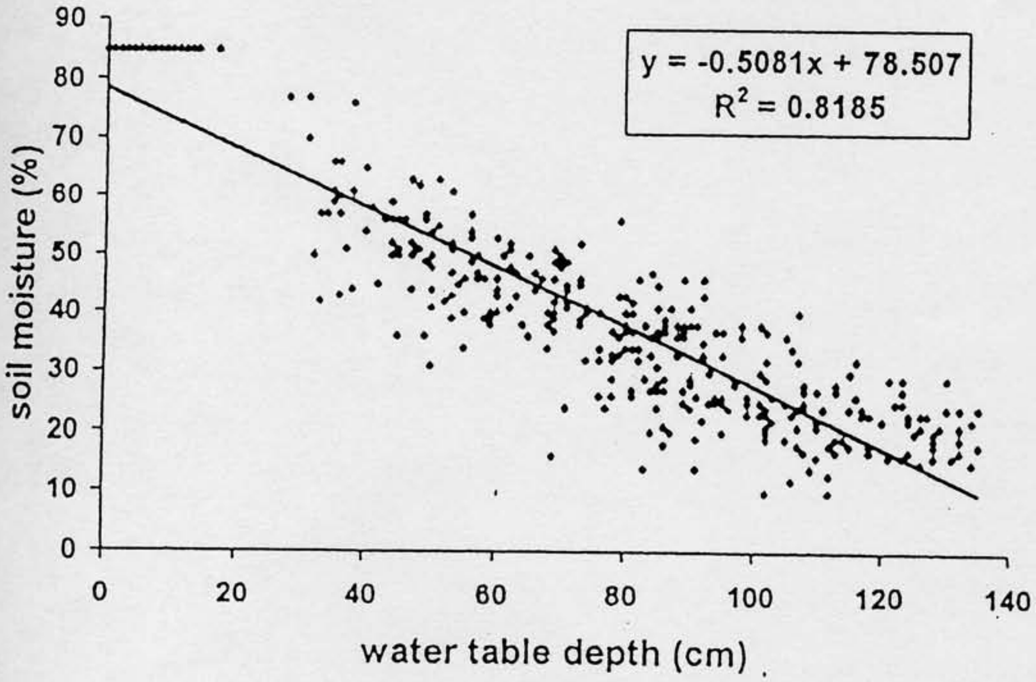

Figure 4. Relationship between percent soil moisture and water table dept,