Regeneration and Distribution of Sycamore and Cottonwood Trees Along Sonoita Creek, Santa Cruz County, Arizona[1]

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Abstract.--This study describes the effects of livestock grazing and streambed erosion on the regeneration and distribution of sycamore and cottonwood trees. Sycamores reproduced from root and trunk sprouts and because of this their distribution is not as likely to change significantly. Cottonwood reproduction was nearly absent in areas grazed by cattle, and was confined to the narrow erosion channel. If this regeneration pattern continues, the future maximum width of the cottonwood forest will decrease nearly 60%.

INTRODUCTION

Many Riparian Deciduous Forests in the Southwest contain extensive groves of sycamore (Platanus wrightii) and cottonwood (Populus fremontii) trees. (Plant community terminology follows Brown and Lowe 1974.) In many areas either one or both of these species are the sole tree component of the riverine habitat. They increase habitat diversity and create invaluable niches for a variety of wildlife, particularly birds (Bottorff 1974, Carothers et al. 1974, Johnson and Simpson 1971, and others).

Along Sonoita Creek in southeastern Arizona cottonwoods exclusively are used as nest trees by rare birds like the Gray Hawk (Buteo nitidus), Zone-tailed Hawk (B. albonotatus) and Black Hawk (Buteogallus anthracinus), and sycamores are the favorite nest tree of the Rose-throated Becard (Platypsaris aglaiae) (pers. obser.).

This study is an assessment of the numbers, condition, regeneration and distribution of these important trees along Sonoita Creek. It provides some basis for comparing populations of these species in areas of varied livestock grazing use. This paper also describes the effects of streambed erosion on the regeneration and future distribution of these trees in riparian habitats of the Southwest.

THE STUDY AREA

Sonoita Creek originates in the Plains Grassland about 1 km northwest of Sonoita, Santa Cruz County, Arizona, and flows in a southeasterly direction through the Desert Grassland to its confluence with the Santa Cruz River 14 km north of the Mexico-United States border. Its 51 km reach occurs along an elevational gradient ranging from 1480 to 1035 m. Its tributaries drain habitats from Boreal Forests at 2865 m elevation through Temperate Woodlands (Madrean Evergreen Woodlands) and Desert Grasslands at 1035 m elevation.

The low hills immediately bordering the creek are covered in moderate density with oaks (Quercus spp.), mesquite (Prosopis juliflora), juniper (Juniperus monosperma), cliff-rose (Cowania mexicana), mountain-mahogany (Cercocarpus sp.) and ocotillo (Fouquieria splendens). Groundcover, consisting mainly of gramma grasses (Bouteloua spp.) and love grasses (Eragrostis spp.), is moderately dense near Sonoita where soils are better developed, and sparser along the middle and lower reaches where steeper hillsides and rockier soils prevail.

The upper 19 km of the alluvial valley-floor from the headwaters to the town of

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Patagonia consist of eroded grass- and scrub-covered plains, irrigated pastures and croplands, and remnants of a Sacaton Grass-Scrub Community. Here surface waterflow is mainly ephemeral. Streambed erosion as reported by Bryan (1925) is a common feature of this upper valley-floor. The erosion, which begins about 2.9 km southwest of Soniota, forms vertical banks 1 to 5 m high and separated by a channel from 15 to 37 m wide. The evidence of this erosion decreases progressively downstream for 5 km, first through weedy grasslands then past irrigated pastureland beginning near Adobe Canyon. For the next 5 km flood-irrigated pastures border the dry creekbed. Erosion produces cuts here less than 2 m high and occurs only locally where the creekbed borders steep hillsides.

The widest reach of this upper alluvial valley is nearly 1 km across and continues for 5.6 km downstream from the pastureland. The flood plain here supports a Sacaton Grass-Scrub Community. In early 1975 many large mesquite trees with basal diameters up to 0.6 m and a few walnut trees (Juglans major) with basal diameters of nearly 0.8 m were removed from here. This area is gradually being cleared of natural vegetation and transformed into irrigated fields. Streambed erosion is absent in the upper 4.0 km of this Sacaton Grass-Scrub plain, where the creekbed branches out among dense sacaton clumps that reach over 2 m in height, but begins about 1.6 km upstream from the lowest reach of this community. Through this eroded reach, vertical banks are 1 to 2 m high and 10 to 40 m apart. Irrigated cropland borders remnants of the Sacaton Grass-Scrub plain about 0.8 km above Patagonia.

Scattered individuals and small clumps of large cottonwood and sycamore trees occur along this upper valley-floor. The predominant tree of this upper floodplain is mesquite, which occurs mainly as a shrub or small tree up to 7 m tall.

About 0.8 km below Patagonia perennial surface water begins and continues downstream for about 19.3 km. Along this reach there is a near-continuous belt of Riparian Deciduous Forest, consisting of cottonwood, sycamore, willow (Salix gooddingii), ash (Fraxinus velutina) and walnut trees. This riparian forest varies in width from 15 to 150 m and in density of trees. It is bordered frequently by small bosques of mesquite and hackberry (Celtis reticulata).

Willow is the most abundant large riparian tree at the head of this forest, and ash is the commonest large tree along the middle and lower reaches. Cottonwood, the third most prevalent tree, is irregularly distributed throughout the forest, and densities of mature tree and sapling cottonwoods vary considerably. Sycamore and walnut are the least common large trees, and occur in small clumps or singly, mainly along the lower reaches of the forest.

The forest floor is covered with annual and perennial grasses and forbs that in some open areas form dense thickets up to 2 m tall after the onset of summer rains in July. In many places livestock grazing and human recreation eliminate summer groundcover by the following spring.

The watercourse, which normally varies in width from 2 to 5 m, is usually less than 10 cm deep, and is often lined with seep-willow (Baccharis glutinosa). In areas that are not grazed by livestock, water-cress (Rorippa nasturtium-aquaticum) blankets the flowing water most of the year.

Since much of the Riparian Deciduous Forest is within the confines of a narrow rocky canyon less than 0.5 km across, alluvial deposits are limited and extensive creekbed erosion is restricted usually to reaches near the entrances of side canyons where alluvium has accumulated. In many areas this erosion has resulted in vertically cut banks up to 4.9 m high. In 1881 a railroad track was completed along the entire length of Sonoita Creek, altering the watercourse along many reaches, including that of the Riparian Deciduous Forest. The railroad levee often constitutes the bank of the creek and contains floodwaters.

The continuity of the Riparian Deciduous Forest was disrupted in the early 1960's with the construction of Lake Patagonia. This lake covers 650 hectares beginning 11.6 km below the head of the Riparian Deciduous Forest and continuing downstream for 3.5 km. Below the dam, surface flow and patches of Riparian Deciduous Forest persist for about 2.9 km.

Thereafter, for the next 11.7 km to its confluence with the Santa Cruz River, Sonoita Creek flows intermittently with scatterings of large cottonwood, ash and willow trees.

The creek proper dissects two general soil types (Richardson in press). Ending about 10 km below Patagonia, the upper type is usually more than 1.5 m deep in old alluvium from igneous and sedimentary rocks and is composed of fine to moderately coarse textured soils with about 35 percent gravel and cobble throughout. The lower type consists of rocky, very cobbly and sandy loams less than 0.5 m deep on weathered granitic, tuff-conglomerate, or andesite-tuff bedrock. Here sediment yield is low.

The most complete climatic data for this area is from Nogales, Arizona, which lies just south of the watershed 27 km southwest of Patagonia and is 1158 m in elevation. Records from 1893 through 1962 show that maximum daily temperatures occurred during June and averaged 34.9°C; minimum daily temperatures occurred during January and averaged -1.4°C. Temperature extremes for the area were -14.4° and 43.3°C. Precipitation was biseasonal, and about 60 percent of the annual average of 396 mm fell during July through September. The driest months were May and April, respectively (Green and Sellers 1964). The spring of 1974 was an extremely dry year and some reaches of the

Riparian Deciduous Forest were without surface flow.

METHODS

From April 1974 through April 1977 I surveyed the trees of the Riparian Deciduous Forest on foot and recorded numbers, height classes, conditions, locations and evidence of regeneration of sycamores and cottonwoods. Multi-trunked trees were counted as one tree if the trunks were joined above ground level. To estimate percentage of sprouting, closely clumped sycamores were counted as an individual tree since they probably shared a common root system. I estimated the numbers of densely clustered seedlings and saplings. Tree heights were estimated and grouped into three size classes: seedling ($<$ 2 m), sapling (2-9 m), and trees ($>$ 9 m). I made brief notes on the conditions of mature trees, especially cottonwoods that had experienced excessive leaf-drop or canopy die-out, or ones with fully leafed canopies that had fallen over for no apparent reason. The numbers and locations of other riparian trees were only casually recorded.

At 100-m intervals I measured the width of the creekbed between the tops of the banks, and the height and approximate slope (to the nearest 30° angle) of the creek banks. To determine the maximum distance that cottonwoods occurred from the creekbed, within each 100-m interval I measured the distance between the edge of the creekbed and the cottonwood farthest removed from the creekbed on both sides of the creek. Lateral bounds of the creekbed often were easily defined by vertically cut banks, but at times were estimated for banks with shallow slopes. Frequently the railroad levee obviously confined the watercourse and was counted as a bank. Bank height and slope were not recorded where the hillside bordered the creekbed. Bank Slopes were classified as shallow (0-30°), intermediate (30-60°) or vertical (60-90°) to the plane of the creekbed.

The Riparian Deciduous Forest was divided into five segments that differed in livestock-grazing use. The grazing practices along Sonoita Creek have varied greatly within the past 100 years, and exact grazing use, past or present, was not measured. However, it is possible to place each of the five segments in different use categories based upon livestock class or use intensity. Segment 1 is 2.7 km long, lies between 1234 and 1204 m elevation, and consists of the Patagonia-Sonoita Creek Sanctuary of the Nature Conservancy, an area fenced to exclude all livestock grazing in 1966. Segment 2 is 2.1 km long, lies between 1204 and 1189 m elevation, and has been grazed by cattle and horses for at least 50 years. Segment 3 is 0.8 km long, lies between 1189 and 1183 m elevation, encompasses the RL Ranch, and has been grazed by horses only since 1966. Segment 4 is 5.9 km long, lies between 1183 and 1143 m elevation at the head of Lake Patagonia, and has been grazed by both horses and cattle for at least 50 years. Segment 5 is 2.9 km long, lies below Lake Patagonia at elevations between 1116 and 1097 m, and has been grazed mainly by cattle for at least 50 years. The soil and vegetation in the upper third of Segment 5 was highly modified in the early 1960's when the dam was built.

RESULTS

Sycamore regeneration, distribution and condition

Sycamores reproduced mainly vegetatively by sprouts from lateral roots and trunk bases. Either root or trunk sprouts were found in 74% of mature sycamores (clumped and individual trees). I never encountered sycamore seedlings, but in Segment 4 I located one sapling that was more than 30 m from mature sycamores and was not a root sprout (Table 1).

Root sprouts occurred on 39% of the sycamores. On the average, root sprouts grew a distance of 1.0 m from the trunk bases (SD 0.5, r 3.0), were 3 m tall (SD 5, r 23), and 5 cm in diameter (SD 10, r 46). Trunk sprouts occurred on 56% of the sycamores and, on the average, sprouted 0.1 m above ground level (SD 0.1, r 0.6), were 3 m tall (SD 3, r 13) and 4 cm in diameter (SD 6, r 28). Trees with root sprouts averaged 8 sprouts per tree (SD 12, r 31), and those with trunk sprouts averaged 6 sprouts per tree (SD 10, r 30). Both root and trunk sprouts occurred on 22% of the sycamores. Root sprouts that were either less than 0.1 m tall or growing among dense debris and brush may have been overlooked, while probably all trunk sprouts were counted.

I was unable to determine what stimulates a sycamore to sprout. There was no significant correlation between either the presence of sprouts or the number of sprouts and the percent of canopy die-out, soil texture at tree base, or proximity of tree to surface water. Possibly the more latent factor of subsurface rock formations affected the presence of groundwater near individual trees and thus their tendency to sprout. The dependence of sprouting sycamores on abundant shallow water remains to be examined.

The large variance in the size of sprouts, some of which themselves were mature trees nearly 30 cm in diameter, indicates that sprouting has been a major means of regeneration along Sonoita Creek for some time. Many even-aged, large sycamores were growing in circular clumps with their trunk bases touching or nearly touching (fig. 1), suggesting that these clumped trees had been sprouts from a common parent tree that has long since decomposed.

Table 1.--Length, grazing use, and numbers of sprouts, seedling, sapling, and mature tree sycamores and cottonwoods for each of five stream segments.

	Stream Segment 1	2	3	4	5	Total
Sycamore						
Sprouts	0	3	0	160	99	259
(Sprouts / km)	(0)	(1)	(0)	(27)	(34)	
Seedlings (< 2 m)	0	0	0	0	0	0
(Seedlings / km)	(0)	(0)	(0)	(0)	(0)	
Saplings (2-9 m)	0	1	0	0	0	1
(Saplings / km)	(0)	(0)	(0)	(0)	(0)	
Trees (> 9 m)	0	7	1	35	15	58
(Trees / km)	(0)	(3)	(1)	(6)	(5)	
Cottonwood						
Sprouts	0	0	0	0	0	0
(Sprouts / km)	(0)	(0)	(0)	(0)	(0)	
Seedlings (< 2 m)	400	500	700	1500	100	3200
(Seedlings / km)	(148)	(238)	(875)	(254)	(34)	
Saplings (2-9 m)	1078	11	586	20	2	1697
(Saplings / km)	(399)	(5)	(732)	(3)	(1)	
Trees (> 9 m)	638	385	68	612	64	1767
(Trees / km)	(236)	(183)	(85)	(104)	(22)	
Segment length (km)	2.7	2.1	0.8	5.9	2.9	
Grazing use	none	cattle & horses	horses	cattle & horses	cattle	

Sycamores were absent in Segment 1 and most abundant in Segment 4 (Table 1) except along the reach where surface flow was absent during the spring drought in 1974. They were distributed most frequently as scattered clumps of up to 10 trees. The clumps occurred from 0 to approximately 140 m from the watercourse (m 33, SD 48). Since regeneration was mostly from sprouting, almost all seedlings and saplings occurred near mature trees.

Livestock had browsed on only 13% of root and trunk sprouts. Most sprouting sycamores were growing on steep banks or amidst brush and litter, which probably prevented cattle from browsing sprouts. Aside from the limited canopy die-out that some trees had experienced, mature sycamore trees appeared healthy. They did not respond to the severe drought in 1974 as did the cottonwoods; however, their occurrence along specific reaches of Sonoita Creek may indicate the presence of abundant surface or subsurface water, thus they would not be expected to reflect initial drought conditions that might affect other trees.

Cottonwood regeneration, distribution and condition

All cottonwood regeneration along Sonoita Creek was from seeds. In July of 1975 cottonwood seedlings about 10 cm high were ubiquitous on moist, sandy alluvium along the watercourse in all segments of the Riparian Deciduous Forest. By the following spring almost all seedlings were absent except those that had germinated in Segments 1 and 3, where cattle were excluded. In January of 1975 cottonwood seedlings were most abundant in Segment 3 (875 seedlings/km) and least abundant in

Figure 1.--Clumped mature sycamore trees.

Segment 5 (1 sapling/km). Segments 1 and 3 averaged 399 and 732 saplings/km, respectively, and Segments 2,4 and 5 averaged 5,3 and 1 saplings/km, respectively (Table 1).

All seedlings occurred below the banks, many immediately along the watercourse. Many cottonwood seeds had germinated on damp soil around isolated, ephemeral pools of rain water that had collected away from the watercourse, but the resulting seedlings wilted and died when the pools became dry several weeks after germination. A continuous supply of supplemental water (treated sewage water) existed in Segment 1, and sustained 93% of the established seedlings outside the creekbed in that segment.

Mature cottonwoods were not evenly distributed throughout the Riparian Deciduous Forest, but were densest in Segment 1 (236 trees/km) and sparsest in Segment 5 (22 trees/km) (see Table 1). The construction of Lake Patagonia Dam eliminated many mature trees from Segment 5. Within each segment cottonwoods were not homogeneously distributed, but occurred with greatest density where alluvial deposits were plentiful. Individual, small clumps or large groves of cottonwoods occurred a mean maximum distance of 26 m from either edge of the creekbed (SD 40, r 196). The mean maximum width of the cottonwood forest, including the creekbed width, was 83 m.

On numerous occasions I observed cattle grazing seedlings on sand deposits along the watercourse. I never observed horses grazing cottonwoods, although many times I saw them nose aside a cottonwood seedling to get at a nearby sprig of grass or water-cress.

The extremely dry spring of 1974 obviously affected many mature and sapling cottonwoods along the entire reach of the Riparian Deciduous Forest. Extensive leaf-drop and canopy die-out occurred in May and June, and many areas of the creekbed and forest understory at that time were blanketed with small, partially developed cottonwood leaves that ranged in color from yellow to yellowish green. Leaf-drop occurred in all segments but was most obvious in Segment 4, where the surface flow failed in May and June along a reach about 150 m long. Many trees regained fully developed canopies after the onset of summer rain in July, but others remained bare and lost large canopy limbs.

Several large cottonwood trees were uprooted in the spring of 1974, having fallen over with canopies in full leaf. The exposed roots of these fallen trees were dry and had been severed less than 1 m below ground level and less than 2 m laterally from the trunk. Uprooting occurred mainly in Segment 1, where five trees fell over. Three trees in Segment 2 and two trees in Segment 4 also were uprooted in early 1974.

Characteristics of valley-floor erosion

Along Sonoita Creek erosion has resulted in banks that are sloped in a shallow, intermediate or vertical manner to the plane of the creekbed. In many instances the shallow and intermediate slopes probably are the result of gradual trampling of once-vertical slopes by livestock. Including the railroad levee, which accounted for 12% of the sampled banks, the average slope of the banks was 56° (SD 17). Nine percent of the sampled banks were vertically cut (fig. 2). The mean height of the banks was 2.3 m (SD 1.6, r 5.8). The width of the creekbed averaged 31 m (SD 23, r 104). There was no trend in these characteristics. Each characteristic was independently and heterogeneously distributed along the valley-floor, and probably reflected the variable alluvium deposits and geometry of the valley-floor.

DISCUSSION

Effects of grazing

Regeneration and distribution of sycamore and cottonwood were affected differently by livestock grazing. The full effects of grazing on sycamore are uncertain, largely because sycamores were absent in Segment 1 where livestock were excluded so the chance of seeds germinating in this segment was reduced. In other segments livestock may have grazed some small sycamore seedlings that I had overlooked, but sycamore seedlings certainly were not common along Sonoita Creek. The germination requirements of sycamore seeds are unknown. Perhaps the soil chemistry of the eroded valley-floor has changed significantly and now inhibits either germination of seeds or growth of seedlings.

Livestock did not heavily browse sycamore sprouts for several reasons: Sprouts were necessarily associated with mature trees and

Figure 2.--Vertical-bank erosion along Sonoita Creek. Cutbank here is 1.5 m high.

thus were scattered and were neither as readily encountered by livestock, nor as easily browsed and trampled as dense clusters of seedlings on exposed alluvium. Small sprouts were frequently well protected and hidden by leaf and branch litter from the nearby mature trees and often the trunks of the parent trees obstructed browsing attempts. Several sprouting sycamores were growing on steep eroded banks or among dense brush, both of which hindered browsing. Also, the stems and leaves of sprouts may be less palatable to livestock than those of seedlings.

Because livestock may graze occasional sycamore seedlings, grazing may be preventing a limited increase in the distribution of sycamores along the streambed. Livestock did not appear to be inhibiting regeneration of sycamores by browsing on sprouts, which constituted the vast majority of sycamore regeneration along Sonoita Creek. These observations indicate that the future distribution of sycamores along Sonoita Creek will be nearly identical to the present distribution, except that where mature trees fail to reproduce vegetatively by sprouting the sycamore will disappear.

Grazing of small seedlings by cattle was the most obvious factor preventing regeneration of cottonwood. Seedlings averaging 9 cm in height and 345 seedlings/m^2 in density were commonly grazed and trampled by cattle. Both the proximity to the creek water, which was used by cattle for drinking, and the unprotected openness of the creekbed alluvium where seedlings occurred made seedlings vulnerable to trampling and grazing by cattle. Horses did not graze seedling cottonwoods, but frequently trampled young seedlings that were growing on open alluvium. Horses did strip the bark from some sapling cottonwoods that had been bent over by flooding.

Thus, by grazing seedlings cattle have severely reduced the establishment of cottonwood in the Riparian Deciduous Forest of Sonoita Creek. In Segments 2, 4 and 5, where cattle have grazed for at least 50 years, the combination of decreased establishment and normal mortality of the mature trees will eventually severely reduce in number or eliminate the cottonwoods from this forest. Dry years such as the one reported for 1974 could hasten the mortality of mature trees and the elimination of the cottonwood.

Effects of streambed erosion

Sonoita Creek flows through the Desert Grassland, a biome which has undergone major vegetational changes in the past century (Hastings and Turner 1965, and others). The erosion that is associated with these vegetation changes consists, in part, of extensive vertical cutting or channeling of the streambeds of major drainages and their tributaries by floodwaters. Both overgrazing by livestock and climatic shifts have been associated with the start of this erosion. Bryan (1925) reported that "Nearly all streams in southwestern United States flow between vertical banks of alluvium that vary in height from 10 to as much as one hundred feet. Although subject to periodic floods, these streams no longer overflow their banks, nor build up their adjacent flood-plains. Floods merely deepen and widen the channels (arroyos) which continually grow headward into the undissected valley floors of the headwater valleys and tributaries."

The extent of erosion along Sonoita Creek is limited by both the width and depth of alluvial deposits in this narrow valley-floor, although the heights of some vertically cut banks have increased up to 0.3 m from 1973 to 1976.

Two significant consequences of this channeling are the containment of floodwaters within the confines of the relatively narrow channel, and the scouring of the vegetation that occurs within the erosion channel. Precipitation that now falls within the Sonoita Creek watershed spends relatively less time in this drainage since the channel quickly transports the water along the valley-floor, preventing water dispersion laterally from the creekbed onto the adjacent floodplain. Such rapid transport may also affect the water table recharge rate.

It seems that once streambed cutting begins it is further perpetuated and accelerated by the concentrated floodwaters in the erosion channel, which transport and remove vegetation and debris that would, prior to the channel, have remained in place and promoted dispersal of less forceful floods, thus decreasing the water velocity and inducing silt deposition. The overgrazed hillsides that border Sonoita Creek no doubt assist in increasing the floodwater velocity since they support relatively less vegetation to intercept precipitation.

I witnessed the effects of channeling on 1 July 1974 when a heavy thundershower occurred over the watershed starting about mid-afternoon. At approximately 1700 hours the water level in Segment 1 had risen almost 0.8 m, and only in unchanneled areas did it overflow laterally onto the shallow banks. The current was swift, removing or flattening vegetation on the shallow banks and scouring most aquatic plants and streamside stands of seedling cottonwoods and willows. Only seedlings that were growing among dense stands of seep-willow remained. The next morning scouring of creekbed vegetation was evident all the way to Lake Patagonia. Relatively few stream terraces had been flooded since the erosion channels or railroad levee had contained the floodwaters. In the afternoon of 2 July the water was still turbid and about 10 cm above pre-flood level in Segment 1. A layer of sand and finer silt had been deposited only on the slightly elevated banks that had been flooded and along the edges of the creekbed where the water had receded.

Coupled with recent erosion are factors of future precipitation trends. Seemingly, higher rates of precipitation would cause more intense flooding and involve a greater volume of water in the channel. Possibly the present extent of channel erosion could not contain such volumes of water and lateral flooding could result. However, if precipitation rate decreases in the future, the chance of lateral flooding would be further reduced by the channel.

The single sycamore sapling in Segment 4 that was not a root sprout had been pushed over by flooding and was partially covered by flood debris. The bark of this sapling was scraped in many places, and it appeared unhealthy and not likely to survive. Possibly sycamore seedlings are intolerant of severe flooding, and mortality from floods during the seedling stage is responsible for decreased regeneration from seeds. Root and trunk sprouts probably suffer less mortality from flooding since they are more solidly rooted and protected by parent trees.

Most cottonwood seedlings were removed by floodwaters. The cottonwood seedlings and saplings that occurred in the erosion channel usually were growing among dense stands of seep-willow, where competition for sunlight and water may affect their survival. Those occurring away from seep-willow were bent over by floodwaters and seemed unlikely to survive, and many such saplings had leaves browsed by cattle or bark stripped by horses.

While the streambed within the confines of the erosion channel transports increasingly more floodwater, the elevated terrace adjacent to the erosion channel becomes increasingly more xeric due to reduced overbank flooding outside the channel and increased depth of the water table as erosion progresses. Since cottonwood seedlings were absent from these benches, it is likely that in the absence of saturating floods they seldom contain the reliable surface water necessary for seedlings to extend tap roots to permanent water. This problem is compounded by increased distance to the ground water on benches.

The ability of mature trees to survive on the benches is questionable for they too must cope with relatively drier conditions. Most mature cottonwoods which had fallen over during the drought of 1974 were growing away from the creekbed on slightly elevated benches. Zimmermann (1969) noted that along the San Pedro River cottonwoods occurred where ground water exceeded 300 feet in depth, and he suspected that some tree species "may depend for growth during at least part of the year only on moisture in the alluvium." Where channeling has increased the depth of the water table and prevented lateral flooding onto benches, the only moisture available to vegetation on these benches may be from precipitation. For cottonwoods and sycamores this may not be sufficient to sustain growth, especially if bench alluvium and topography permit rapid runoff of precipitation. If mature sycamores require saturated alluvium for sprouting, the frequency of sprouting may decrease with increased erosion.

SUMMARY AND CONCLUSION

Sonoita Creek provided comparison of regeneration of sycamore and cottonwood trees in areas of various livestock grazing uses. It also afforded observations on the relation between regeneration and streambed erosion, which along Sonoita Creek is limited yet effective in containing and quickly transporting floodwater along the valley-floor, and ultimately in transforming the broad cottonwood forest into a relatively narrow strip of trees that grow in the erosion channel.

Livestock grazing did not appear to prevent regeneration of sycamores, which produced by sprouting from roots and trunk bases. The apparent absence of sycamore seedlings may be related to the erosion and turbid flooding that now periodically occurs in this drainage. Because of vegetative reproduction, sycamore distribution along Sonoita Creek is not likely in the near future to change appreciably from its present distribution unless mortality of sprouts occurs. An increase in soil aridity associated with the erosion channel may induce sprout and parent tree mortality.

Cottonwood, which reproduced from seed, was nearly absent in stream segments grazed by cattle, but abundant in areas grazed by horses only. Because stream flow needed for cottonwood regeneration is confined to the eroded channel, all cottonwood regeneration is confined to this narrow habitat, which averaged 31 m wide. The present mean maximum width of the cottonwood forest including the pre-erosion remnants is 83 m. Thus the future maximum width of the cottonwood forest along Sonoita Creek will decrease nearly 60 percent if the present natural regeneration pattern continues.

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