Effects of Domestic Livestock Grazing on Water and Soil Resources of the Bar X Allotment

Tonto National Forest

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INTRODUCTION

The purpose of this report is to assess the effects of domestic livestock grazing on water and soil resources of the Bar X grazing allotment. A prerequisite to understanding such an assessment is a basic knowledge of the effects which excessive livestock grazing can have on soil-water-vegetation relationships. Consequently, a brief discussion of these relationships will precede the evaluation of the Bar X allotment.

EFFECTS OF OVERGRAZING ON WATER AND SOIL RESOURCES

The renewable water resources produced by the Tonto are ultimately derived from rain and snow. Once this precipitation strikes the land surface, several different things can happen: The water can be evaporated back into the atmosphere, it can be stored in the soil mantle, or it can run off. Runoff can take several forms. Certainly the most obvious is surface runoff which travels over the soil surface to adjacent streams and lakes. Not so evident is subsurface flow which results from precipitation sinking into the the soil and flowing laterally into adjacent waterways or groundwater flow which percolates downward to the ground water table.

Excessive livestock grazing can modify the natural cycle of precipitation and runoff by changing soil and vegetative conditions. More specifically, overgrazing tends to increase the amount of surface runoff by: 1) compacting the soil surface, and 2) reducing the amount of vegetative material protecting the soil surface.

Trampling by livestock applies pressure to the soil surface. For instance, Lull (1959) noted that a cow can exert a pressure of 24 pounds per square inch (psi) while sheep exert approximately 9 psi. This pressure can materially alter soil structure by reducing the amount of pore spaces. Flory (1936), in comparing the soils of an undergrazed, overgrazed and depleted range in New Mexico, found the pore space to be 68.1, 51.1 and 46.5% respectively. This reduced pore space in turn allows less precipitation to enter the soil. In the study by Flory (1936), 10.5 centimeters of water per hour entered the soil on the undergrazed range compared to 5.5 cm per hour on the overgrazed range and 2.1 cm on the depleted range. Similarly, Leithead (1959) found that a range in good condition absorbed moisture five to six times faster than the same range in poor condition.

Simply stated, heavy livestock grazing compacts the land surface which allows less precipitation to sink into the soil. More of this precipitation is then forced to flow off the site as surface runoff. Soils are particularly susceptible to compaction when they are wet. Grazing during these wet periods is inevitable on ranges used continuously throughout the year.

A reduction in vegetative ground cover exposes more bare soil to raindrop impact which can dislodge numerous soil particles and partially seal the soil surface. Measurements have shown that raindrops can splash soil particles to a height of over two feet vertically and more than five feet horizontally on level surfaces (Millar, Turk, and Foth, 1951). This process causes larger soil particles to break up into very fine material which fills pore spaces and slows the entrance of water. According to one source (Gray, 1970), larger pore spaces may be reduced by two-thirds through raindrop impact on soils unprotected by surface litter. This sealing process also results in more surface runoff.

The fact that overgrazing can increase surface runoff has generally been demonstrated in numerous studies throughout the Western United States (Dunford, 1949 and Lusby, 1970). In one study conducted on the Tonto National Forest, surface runoff during the summer rainy season was six times greater on an overgrazed plot than on an ungrazed control (Martin & Rich, 1948).

In the process of developing a method to predict storm runoff, the Soil Conservation Service has conducted numerous studies. These studies have shown that less vegetative ground cover produces more storm runoff. A specific example of this type of relationship is shown in Figure 1.

The consequences of increasing surface runoff through overgrazing are several fold. Certainly the loss of moisture that would otherwise be available for plant growth is an important factor. According to Stoddart, Smith and Box (1975), increased runoff "reduces the effectiveness of precipitation and makes ranges even more arid than they are normally, further reducing their ability to produce forage."

The increased water which flows across overgrazed ranges is also the primary force causing soil particles to move downslope. The high rates of erosion associated with lack of adequate vegetative ground cover have also been well established. For example, increased vegetative cover resulting from improved range and livestock management reduced the average annual rate of sediment production approximately 71% on a watershed in New Mexico (Aldon and Garcia, 1973).

It should also be noted that selective grazing by livestock may also effect erosion by changing species composition. More often than not, it seems that the plant species preferred by livestock are the ones most effective as soil stablizers (Meeuwig and Packer, 1976).

Severe erosion lowers site productivity. In other words, erosion impairs the ability of an area to produce vegetation. A reduction in plant growth limits the output of commodities, such as forage and timber, tends to degrade wildlife habitat and has other negative affects.

Once the surface soil is eroded, its replacement in the semi-arid climate of the southwest is extremely slow. Some scientists (Curry, 1973) feel that many of the soils in the west were formed 10,000 to 1 million years ago under wetter conditions. He feels these soils "are not forming today and cannot under today's climatic conditions." At any rate, once soils are lost through erosion, their replacement in the semi-arid portions of the southwest is an extremely slow process taking hundreds of years.

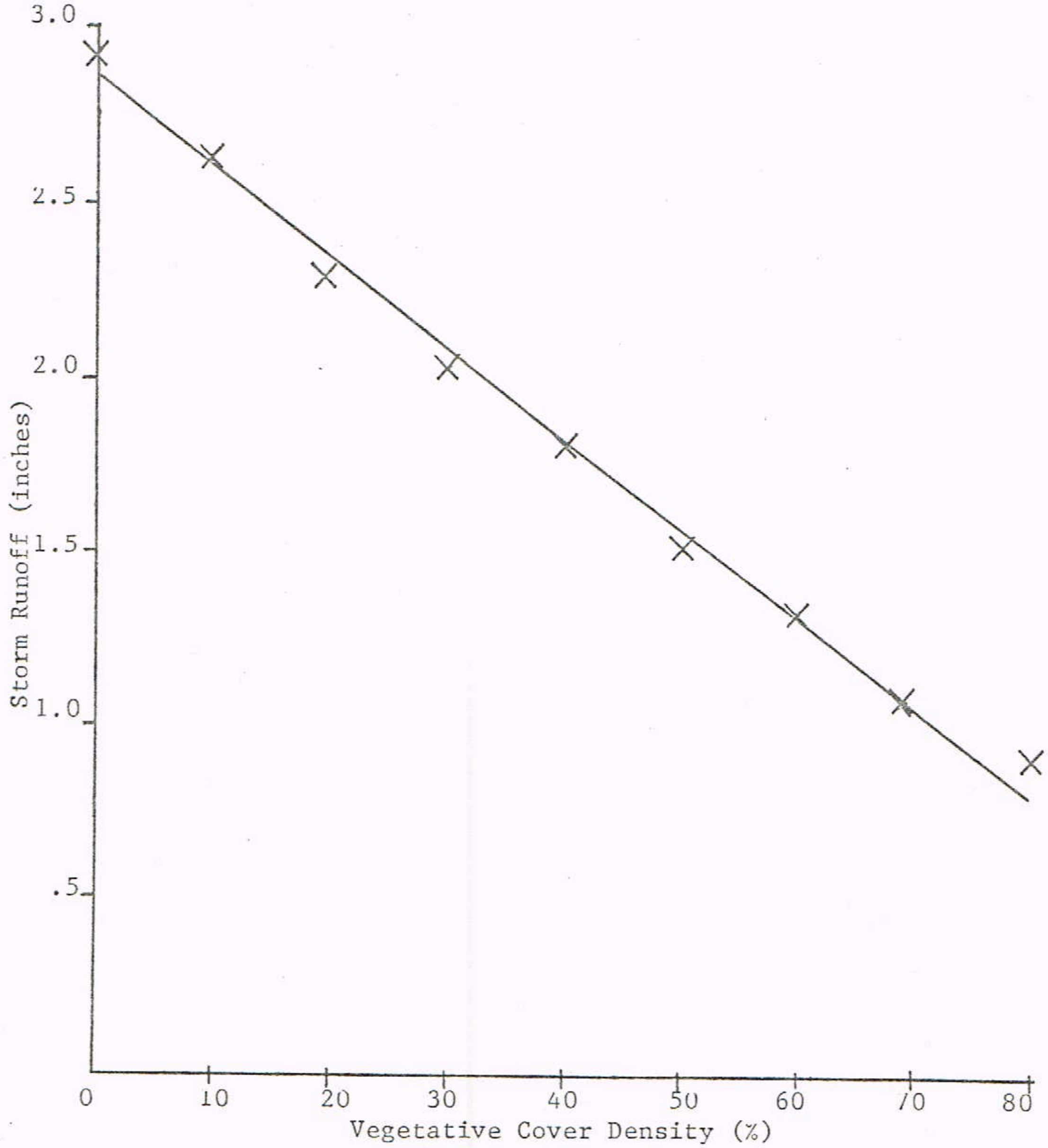

Figure 1. An example of the type of relationship that exists between vegetative cover density and storm runoff as determined by the Soil Conservation Service. This particular graph indicates the runoff that could be expected from a 4 inch rain (10 year-24 hour storm) in the pinyon - juniper vegetative type on a soil having below average infiltration capacity (Group C).

Some of the soil lost through water erosion eventually reaches adjacent streams and lakes. This sediment can seriously degrade aquatic habitats by hindering fish production, smothering food organisms, destroying spawning grounds and filling pools (McKee & Wolf, 1963). Sediment also shortens the life of man-made reservoirs and clogs water distribution systems. Public Law 92-500 (Federal Water Pollution Control Act Amendments of 1972) mandates a comprehensive campaign to prevent, reduce and eliminate water pollution. Under the provisions of this act, sources of excessive sediment must be identified and controlled.

Figure 2 indicates some of the basic cause and effect relationships that can result from overgrazing. To summarize, overgrazing tends to increase surface runoff by compacting soils and reducing vegetative ground cover. This increased runoff results in less moisture available for plant growth and accelerated erosion. Erosion reduces site productivity and the resultant sedimentation can degrade aquatic habitats and clog water distribution systems.

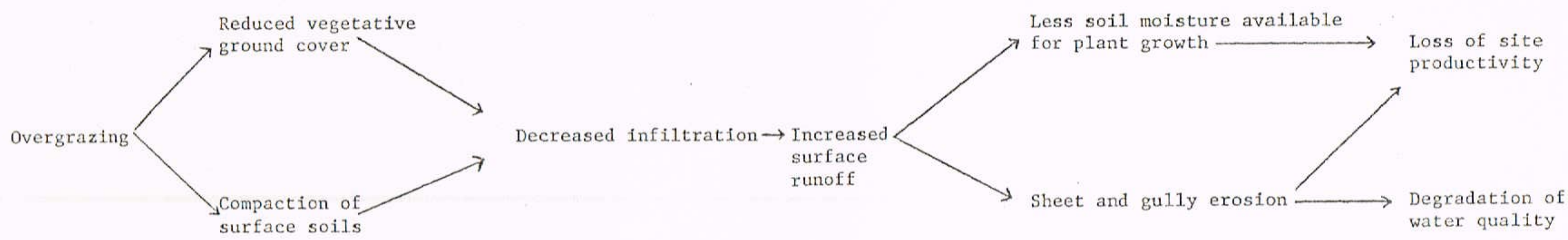

Figure 2. Some of the cause and effect relationships that result from overgrazing.

DESCRIPTION OF AREA

The Bar X grazing allotment is located in central Arizona on the Tonto National Forest (Figure 3). The allotment encompasses approximately 55,000 acres. Elevations range from 4,600 feet near the old Ellinwood Ranch to 7,600 feet along the Mogollon Rim.

The topography of the area varies considerably. Gently rolling hills and valleys dominate much of the pinyon-juniper areas several miles north of Young, while steep escarpments characterize the Naegelin and Mogollon Rims.

The climate of the Young area is moderately moist (Green and Sellers, 1964); the average annual precipitation being 19.4 inches. Figure 4 depicts the mean monthly precipitation throughout the year. As can be seen from this graph, there are two separate seasons when most of the precipitation in this area is received.

During July and August, moisture from the Gulf of Mexico sweeps into Arizona from the southeast around a high pressure cell protruding into the central part of the U.S. (Green and Sellers, 1964). This moist air, coupled with the warm daytime temperatures, leads to numerous short duration high intensity thunderstorms. From December through March, moisture is derived primarily from storms moving eastward from the Pacific coast. Precipitation from these storms is usually light but widespread and may continue for several days. Less than one-fourth of the winter precipitation at Young falls as snow. This percentage increases appreciably, of course, at the higher elevations on the allotment.

The only long-term weather station near the Bar X grazing allotment is at Young, Arizona. An analysis of the U.S. Weather Bureau records indicates that the average annual precipiation during the past ten years (1968 to 1977) has been 95% of the long-term 30 year average*. During six of the last ten years, Young received below average precipitation, while during the other four years it received above average precipitation (Appendix A). This is not unusual, as the majority of the years at most locations in Arizona are drier than the long-term average. This can be attributed to a few extremely wet years which tends to raise the long-term average above the average amount that can normally be expected on a year to year basis. The lowest precipitation total during the past ten years occurred in 1975 when 74% (14.35 inches) of the long-term average was received. The highest total recieved was 113% (21.96 inches) in 1972.

*For calculations purposes, the 1977 year only included the nine month period from January through September. The October through December data was not yet available at the time when this report was written.

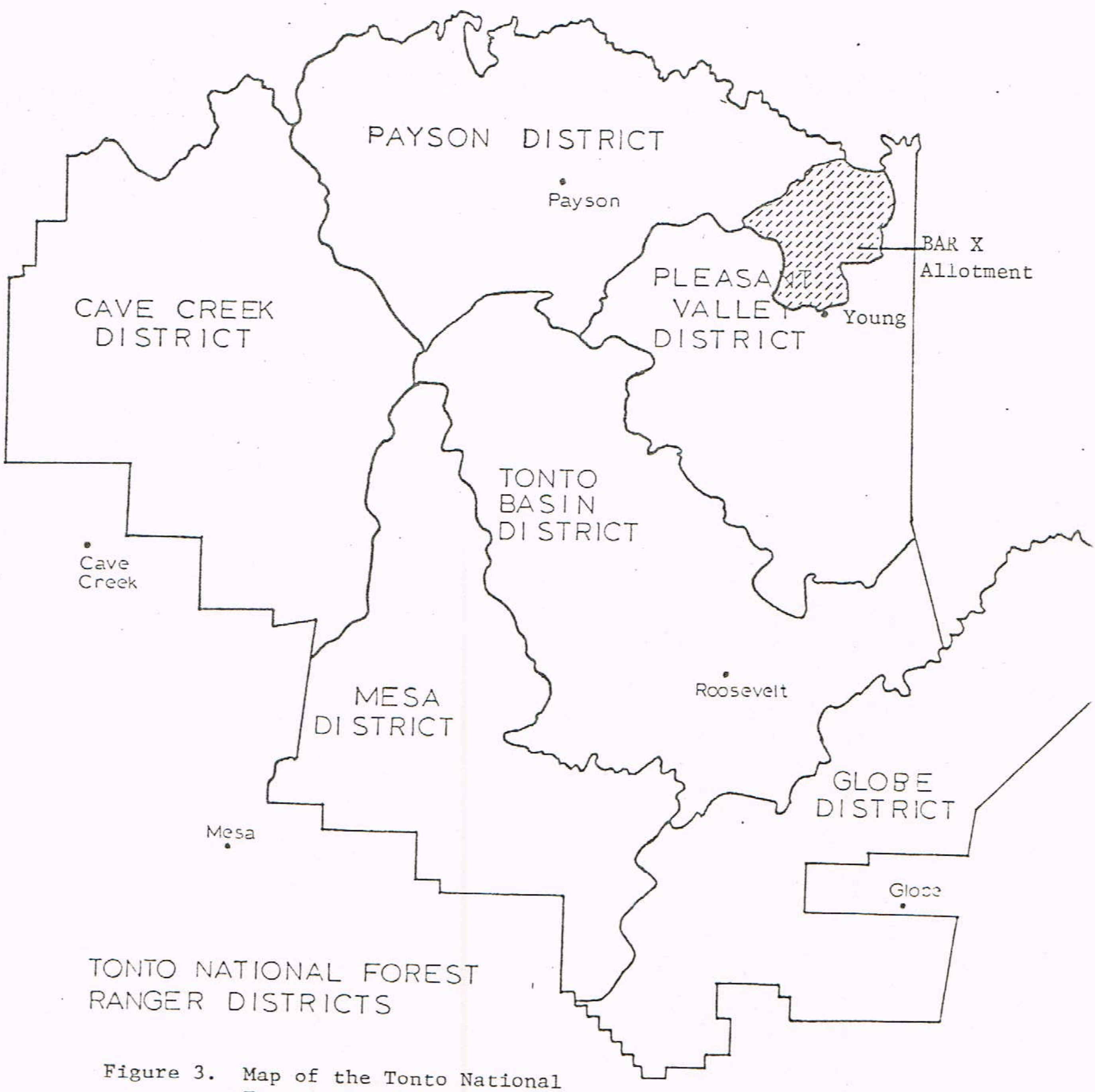

Figure 3. Map of the Tonto National Forest showing the location of the Bar X grazing allotment.

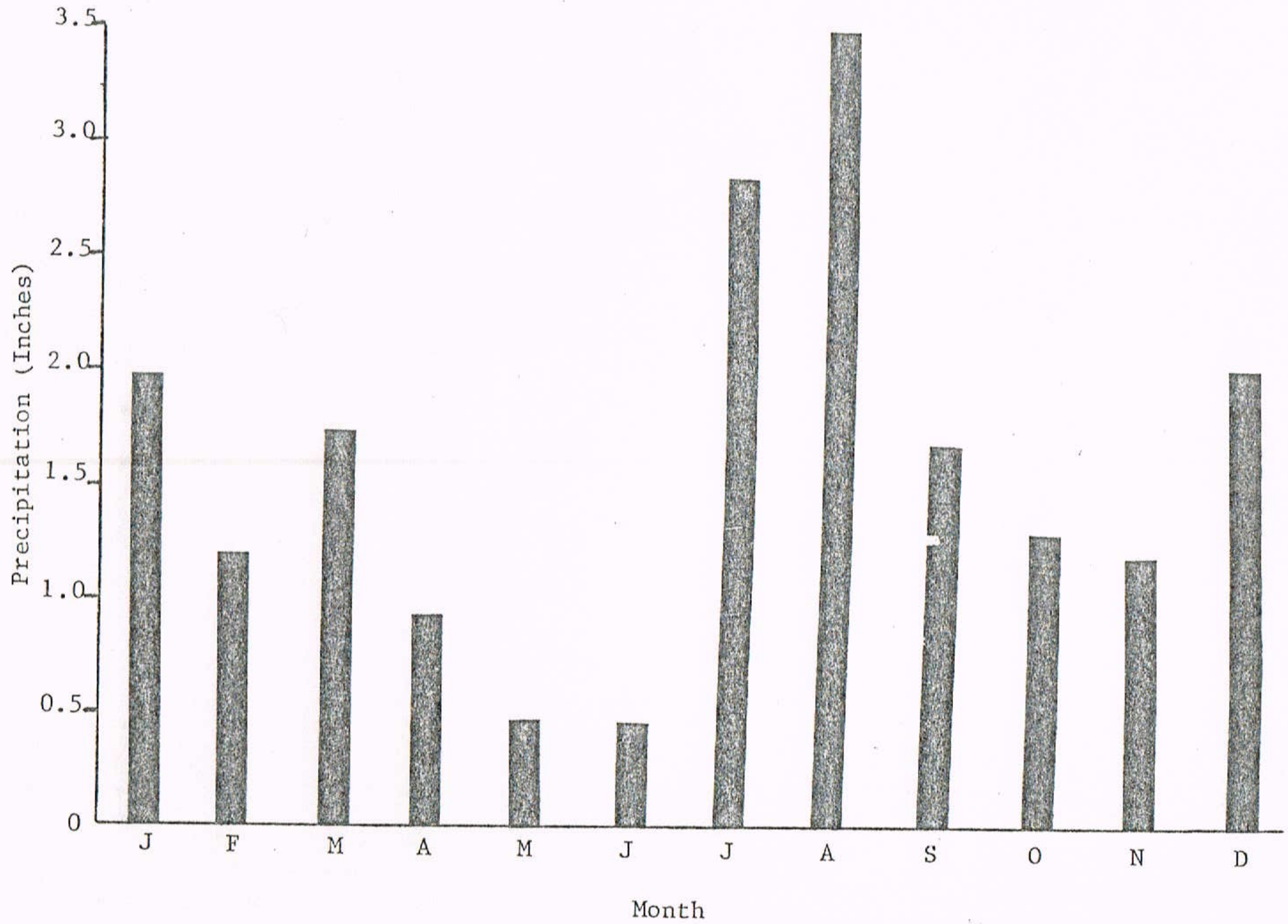

Figure 4. Average monthly precipitation at Pleasant Valley, Arizona based on 30 years of record from 1941 through 1970. Average annual precipitation equals 19.37 inches.

Perhaps more important than year-long precipitation is the moisture received just prior to and during the growing seasons. For this reason, the moisture received from January through April and July through September during the past ten years was also analyzed. During the January to April period, precipitation was 88% of the long-term average with six years below average and four years above average. Between July and September, precipitation was also 88% of the long-term 30 year average with six years below and four years above average.

In addition to the long-term record at Young, a cooperator has been collecting precipitation data at Colcord Estates since 1971. Colcord Estates is located in the northern part of the allotment one and a half miles south of the Mogollon Rim. Records at this station (Appendix A) indicate that precipitation has varied between 25.5 and 31.1 inches during the past six years. U.S. Weather Bureau maps indicate that this area normally receives 25 to 30 inches of precipitation annually. Thus, moisture received during the past six years at this station has not deviated appreciably from estimates of the long-term average.

It should be noted that field observations for this hydrologic evaluation and report were made primarily during the fall of 1976 when moisture conditions were slightly above average.

The surface geology of the area is complex. Rock materials between the Mogollon Rim and the Naegelin Rim are predominately sandstones, limestones and shales. Much of the area north of Young is composed of alluvial material such as gravel, sand and silt. Granite and schist are also present in the southwestern portions of the allotment.

The vegetation in this area can be classified into several basic communities. From the higher elevation (moister-cooler) sites to the lower elevation (drier-hotter) sites, these include: Douglas fir-white fir, ponderosa pine, chaparral and pinyon-juniper. In addition, the riparian vegetative community is found along the water courses throughout the allotment.

EVALUATION

Due to the large and complex nature of the Bar X grazing allotment, a discussion of the hydrologic condition of the area will be by vegetative community (these communities are patterned after those presented by Brown and Lowe, 1974).

1. Douglas Fir-White Fir Community

This vegetative community is extremely limited in extent on the Bar X, occupying only the more moist sites at the higher elevations.

Characteristics

The dominate overstory species comprising this forest include Douglas fir, white fir and ponderosa pine. Also present are gambel oak, maple and a few quaking aspen. Annual precipitation is approximately 30 inches and is normally in excess of potential evapotranspiration. Summer and winter precipitation totals are almost equal, but 75% or more of the stream flow normally comes from winter snowfall (Rich & Thompson, 1974). This and other "mixed conifer" forests generally have higher water yields than any other forest type in Arizona (Ffolliott and Thorud, 1974).

Findings

In the areas examined, very little herbaceous vegetation is present on the forest floor (Figure 5). This can be attributed primarily to the dense overstory vegetation which blocks sunlight and thus hinders the development of understory forage species such as the grasses (Humphrey, 1960).

Despite the lack of vegetative ground cover, accelerated erosion was not prevalent in the Douglas fir-white fir communities examined. For one thing, leaves and other dead organic matter adequately protect the soil from raindrop impact. This allows more moisture to enter the soil and slows surface runoff.

In addition, the lack of available forage in these areas discourages intensive livestock use. As a result, trampling damage to the soil is less likely to occur.

2. Ponderosa Pine Community

Ponderosa pine dominates the northern portion of the Bar X allotment between the Mogollon Rim and Naegelin Rim. Scattered stands also occur in the other sections of the allotment on the more moist sites including canyon bottoms and north facing slopes.

Figure 5. A typical view of the forest in the Douglas fir-white fir community. Notice the lack of direct sunlight and herbaceous vegetation, and the presence of a protective litter layer.

Figure 6. A fenceline contrast showing an ungrazed study plot on the left and cattle range on the right. Although this area is located several miles east of the Bar X, it typifies conditions currently found on the allotment. The lack of herbaceous vegetation greatly increases the potential for soil erosion.

Characteristics

As the name implies, ponderosa pine is the dominate overstory species in this vegetative community. However, Douglas fir normally grows in association with the pine on the more moist sites, while alligator juniper occurs in large numbers on the drier sites. Gambel oak is also prevalent throughout the area.

Average annual precipitation is estimated to be 25 inches. As in the Douglas fir-white fir community, the precipitation falling during the winter is the major source of runoff. It should be noted that the ponderosa pine forests in Arizona are very important water producers—yielding an average of 2 to 6 inches of runoff annually (Ffolliott & Thorud, 1974) over vast acreages.

Findings

Perhaps the most obvious feature common to the ponderosa pine community on the Bar X allotment is the lack of herbaceous vegetation on the forest floor. Generally, this is not characteristic of ponderosa pine forests which, unlike the Douglas fir-white community, are more open and have the ability to produce abundant forage (Stoddart, Smith and Box, 1975). Certainly, the ponderosa pine community on the Bar X has the ability to produce substantially more forage. This is evident from examining several fenced areas where grazing by domestic livestock has been excluded for a number of years. Within these fenced areas, grasses, including long tongue muhly, mountain muhly, bullgrass and pine dropseed, are evident. Outside the plots, grazing has all but eliminated the major forage producing plants (Figure 6). This lack of vegetative ground cover greatly increases the possibilities for more surface runoff and erosion.

In some areas, particularly where the pine stands are relatively dense, little erosion is occurring. Again, this can be attributed to the dead organic matter, such as pine needles, that protects the soil from raindrop impact and slows surface run (Figure 7).

In other areas, erosion is extremely severe. For the most part, this erosion is occurring (1) on relatively dry open ponderosa pine sites where the overstory vegetation does not produce enough litter to adequately protect the soil or (2) where excessive livestock concentrations have removed most of the protective litter layer. Lacking both herbaceous vegetation and litter, these areas are particularly susceptible to soil detachment by raindrop impact and soil movement through surface runoff. Many of the south and west facing slopes near Lost Salt Spring, lower Colcord Canyon, upper Haigler Canyon and the Naegelin Rim exemplify these conditions and are eroding badly. Evidence of erosion includes the pedestaling of plants, the presence of numerous rills (Figure 8), and the deposition of large quantities of sediment behind brush and other debris.

Figure 7. A dense mat of pine needles helps to protect the soil, even though herbaceous vegetation is absent.

Figure 8. Rill erosion on the Bar X allotment. Without a protective soil cover, such as grasses and litter, these small channels will become larger and could develop into gullies. The lack of vegetative ground cover in this particular area can be attributed to both mechanical disturbances and grazing.

It is difficult to describe the severity of erosion in the Naegelin Canyon area near Clay Springs. As Figure 9 indicates, the hillsides are almost totally devoid of understory vegetation and litter. Without this protective vegetative "coating", surface runoff has washed away the productive topsoil, leaving behind the heavier gravel and rocks. The topsoil that once occupied the slopes is being deposited in the bottom of Naegelin Canyon (Figure 10) and eventually finds its way further downstream.

On September 2, 1976, I had the opportunity to observe this area during a rainstorm. This storm was of moderate intensity, lasted only a few minutes and deposited an estimated 0.20 inches of water. Prior to the storm, the Naegelin canyon area and the creek itself were dry. After the storm, surface runoff poured off the hillsides loaded with silt (Figure 11). Naegelin Creek began to flow shortly after the storm abated, further transporting the sediment downstream. In essence, this short lived stream-flow was conveying the detrimental effects of improper land mangagement in Naegelin Canyon to other lower elevation areas downstream.

A watershed in a healthy condition with adequate ground cover would not have responded in this manner. Characteristically, there would have been very little surface runoff and what water did reach the stream would have been relatively free from silt.

The unraveling of Naegelin Canyon can be attributed primarily to excessive livestock grazing which has removed the ground cover. Certainly, the trailing of sheep over the Heber-Reno Driveway through the canyon year after year has hastened its deterioration. A fenced wildlife study plot established in the bottom of the canyon in 1960 graphically illustrates the effect livestock grazing is having on this area (Figure 12). While ground cover conditions vary considerably within the plot, they are far superior to the denuded land surrounding the fenced area. Figure 13 shows an area within the plot that has excellent ground cover.

The problems in Naegelin Canyon are not recent. A watershed condition survey conducted in 1963 noted that " .... sheet erosion on the lower slopes and along both sides of the canyon bottom is severe" (Reynolds & Connelley, 1963).

3. Chaparral (Evergreen Sclerophyll) Community

The occurrence of the chaparral vegetative community is limited on the Bar X allotment. Much of the chaparral occurs in a narrow band that runs from southeast to northwest along the face of the Naegelin Rim. A few scattered stands are also evident in other areas of the allotment such as on Ox Bow and Round Mountains. For the most part, these communities occur between 5,500 and 6,500 feet on steep slopes.

Figure 9. Sheet erosion on the sideslopes of Naegelin Canyon is so severe near Clay Springs that much of the topsoil has been lost. Only the heavier materials including the rocks remain on the hillside.

Figure 10. Since this fence was constructed in 1960, sediment from the adjacent hillside (in Naegelin Canyon) has buried much of its lower half.

Figure 11. Surface runoff from a hillside in Naegelin Canyon after a small rainstorm. Notice the lack of grasses and other herbaceous plants that would normally help slow such runoff so that it could sink into the soil. Also note the muddiness of the water which indicates that the soil resource is being washed downslope.

Figure 12. The area in the foreground has not been grazed since 1960, whereas the hillside in the background is grazed by both sheep and cattle. With the exception of a few oak leaves, the grazed area is almost devoid of under-story vegetation and litter.

Figure 13. Excellent vegetative ground cover that can be found in the Naegelin Canyon wildlife study plot. This dense growth of grass will provide the protection necessary to hold the soil in place.

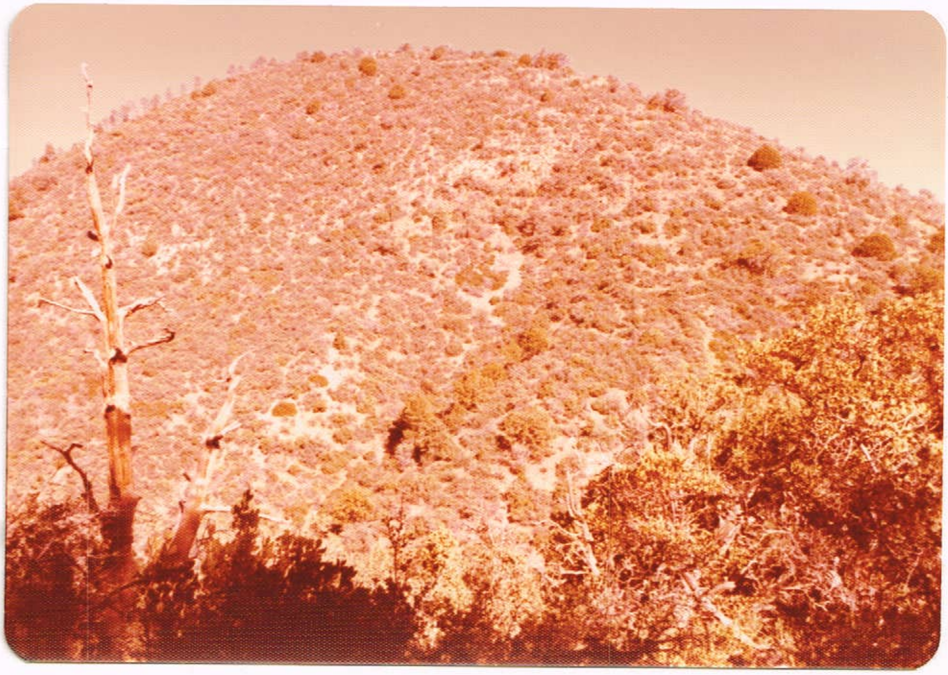

Figure 14. A typical chaparral vegetative community on the Bar X allotment. Notice the steep slopes and the moderately dense to open spacing of the individual shrubs.

Characteristics

According to Brown and Lowe (1973), "Dominant chaparral plants are characteristically tough-leaved evergreen shrubs that form a dense brushy growth, usually closed or not widely open, of fairly uniform height between 3 and 6 or 7 feet, broken by an occasionally taller shrub or short tree that is usually an oak or juniper." Shrub live oak is the dominate species comprising the chaparral on the Bar X. Manzanita and mountain mahogany are also prevalent. Average annual precipitation is estimated at 23 inches. Mean annual water yields in Arizona vary from 0.1 to 3.0 inches (Ffolliott and Thorud, 1974) with approximately 85% of this runoff occurring between December and April (Hibbert, Davis and Scholl, 1974).

Findings

The spacing of shrubs in the chaparral areas examined can be described as moderately dense to open (Figure 14). As a result, one would expect to find grasses and forbs in the intershrub spaces (Hibbert, Davis and Scholl, 1974; Ffolliott and Thorud, 1974; Stoddart, Smith and Box, 1975). This was not the case, however, on most of the Bar X. The few perennial grasses observed were heavily utilized, as were the more palatable shrubs.

Despite the livestock use and the steep slopes, water caused erosion was not severe in the areas examined. This observation coincides with research results on the Three-Bar Experimental Watersheds, which demonstrated that chaparral is capable of holding erosion rates to relatively low levels (Hibbert, Davis, and Scholl, 1974). It does appear, however, that some soil and rock material is moving down slope under the influence of gravity. Any surface disturbances, such as trampling by livestock, are undoubtedly hastening this erosional process.

4. Pinyon-Juniper Community

This community occurs over large areas between the Naegelin Rim and the southern allotment boundary. Scattered stands are also found north of the Naegelin Rim on the drier sites.

Characteristics

The dominate overstory species in this community includes pinyon pine, alligator juniper and Utah juniper. Characteristically, alligator juniper and pinyon pine occur at the higher elevations, mixing with ponderosa pine at the upper limits of their range. Alligator and Utah juniper, along with Emory oak, are the dominate overstory species at the lower elevations.

Stand density varies considerably, ranging from relatively dense pinyon pine "forests" to open savannas containing scattered junipers and an understory of grasses and forbs. It could be argued that these open savannas are actually grasslands being invaded by woody plants. However, for the purposes of evaluating water and soil resources on the Bar X, these savannas will be considered as part of the pinyon juniper woodland.

Average annual precipitation is estimated at 20 to 23 inches while runoff normally averages less than one inch per year (Ffolliott and Thorud, 1974).

Findings

Several different types of pinyon-juniper communities have been recognized in Arizona. According to Jameson (Springfield, 1976), the type found on the Bar X (dominated by alligator juniper, Utah juniper, and pinyon pine) has the greatest capability to produce forage. This is not surprising when one considers the relatively moist warm climate and open savanna-like nature of this vegetative community.

Despite the ability to produce understory vegetation, current ground cover conditions on the Bar X are inadequate. For one thing, the density of perennial grasses has been greatly reduced. This is evident from observations of the Pine Creek Study Plots which are fenced to exclude livestock. Within the plots, vegetative ground cover is approximately 46% (Figure 15) while over much of the pinyon juniper range, ground covers less than 20% are common (Figure 16). In addition, many of the perennial grasses have been replaced by annual forbs. As these plants only live through one growing season, their root system is generally much less extensive than the roots of a perennial grass. As a result, the annuals are much less capable of holding the top-soil in place. Figure 17 shows the root system of two plants commonly found on the Bar X: Aster, an annual forb and hairy grama, a perennial grass. As the photograph indicates, the root system of the annual forb is small in comparison to the perennial grasses.

It appears that domestic livestock grazing has also altered the soil surface of these rangelands. The soils in the Pine Creek Study Plots are loose, friable and have a spongy feel. To the contrary, the soils in the grazed pastures adjacent to the study plots have a much harder surface. In an effort to determine if this difference was statistically significant, 200 penetrometer readings were taken inside the plots and 200 measurements in adjacent pastures outside the plots. The means and standard deviations of these readings are as follows:

	Outside (grazed)	Inside (ungrazed)
Mean	2.29	1.57
Standard Deviation	1.60	1.23
Sample Size	200	200

Figure 15. Vegetative ground cover conditions within the Pine Creek Study Plots. As the photograph indicates, the pinyon-juniper community on the Bar X has the capability to grow abundant forage.

Figure 16. Where sheep and cattle have been grazing, range conditions differ markedly from those found a short distance away in the Pine Creek Study Plots. Perennial grasses have been grazed to the ground and sheet erosion is evident.

Figure 17. The root system of the native perennial grass on the left (hairy grama) is much more capable of holding the soil in place than is the root system of the annual forb (aster).

Figure 18. When soils are wet, they are particularly susceptible to trampling damage by livestock.

The Students' t Test was used to compare the two means at the .01 level of significance. This test indicated that there is a highly significant difference between the means (Appendix B). Thus, it appears that the soil surface near the study plots has been altered to some degree by livestock grazing. Figure 18 shows some of the visual effects of trampling damage.

These poor range conditions affect surface runoff. In order to quantify these effects, surface runoff under current range conditions was compared to the estimated runoff that would occur if the range were in good condition. The Soil Conservation Service (SCS) method of predicting storm runoff was used to make this comparison on a three square mile watershed located south of the Naegelin Rim. This method takes into account soil properties and vegetation conditions, including ground cover density. Assuming a storm produced 1.4 inches of rain in one hour (10 year-1 hour design storm), the predicted runoff under present range conditions would be 0.7 inches (Appendix C). Thus, when vegetative ground cover density is only 20% (current conditions), approximately one-half of the storm's rainfall appears as surface runoff. For comparative purposes, it was assumed that the vegetative ground cover density under good range conditions would be 46%--this being the level of protection that currently exists within the Pine Creek Study Plots. Under these conditions, a 1.4 inch rain would produce 0.5 inch of runoff. Thus, in this particular case, surface runoff would increase approximately 23% as a result of overgrazing.

We can carry this analysis one step further and estimate the maximum streamflow (peak flow) that would occur at the mouth of this watershed under both poor and good range conditions. Again, using a standard SCS technique (Appendix C), peak flows resulting from the design storm (1.4 inches) were calculated at 1040 cubic feet per second under current range conditions (20% vegetative ground cover). This compares to a peak flow of 805 cfs for the same watershed in good range condition (46% vegetative ground cover). Thus, the peak flow in this specific example was increased almost 30% as a result of overgrazing.

Erosion varies with the velocity of the water in motion and the natural erodibility of the soil. As increased peak flows normally have greater velocities, they also have the ability to erode more soil. More specifically, erosion varies approximately as the second power of stream velocity (Stoddart, Smith and Box, 1975). This means that doubling the velocity of moving water will increase its eroding power by four times.

The net result has been accelerated (man induced) sheet and gully erosion that is both severe and extensive. Evidence of sheet erosion includes the visual loss of topsoil (Figure 19), pedestaled plants and the accumulation of sediment behind logs and other debris (Figure 20). Perhaps the most striking feature of the area, however, is the extensive network of gullies. Active erosion is now occurring in these gully bottoms. This down cutting is evidenced by the "V" shaped channel bottoms and the raw channel banks which lack vegetative cover. Active erosion is also occurring at the beginning or "head" of the gullies. This head cutting is advancing the gullies upslope (Figure 21). A comparison of aerial photographs taken in 1946 and 1975 indicates that some of the gullies have cut upslope as much as 80 feet in the last 30 years.

Overgrazing is undoubtedly contributing to the active gully erosion that is currently prevalent on the Bar X. Evidence of this can be found in the Pine Creek Study Plots. Within the plots, the head-cutting is slowing or has actually stopped. In addition, the gully bottom and sides have rounded-off and vegetation is holding them in place (Figure 22).

The erosion on the Bar X allotment is seriously affecting the productivity of the pinyon-juniper rangelands. Forbs and other less productive plants tend to dominate those areas where sheet erosion has removed much of the topsoil. And as one might suspect, the actively eroding gullies will reduce the area's ability to produce forage for years to come. This loss of productivity is significant when one considers that the pinyon-juniper range provides the bulk of the grazing capacity on the Bar X allotment.

5. Riparian (Mixed Broadleaf) Community

The word riparian is defined as "Pertaining to or situated on the bank of a body of water" (Webster, 1972). Thus, by definition, the riparian vegetative community occurs along drainages throughout the allotment.

Characteristics

The vegetation comprising this community is distinctly different from that of immediately surrounding nonriparian communities. Generally, riparian areas are characterized by deciduous broad leaf trees. On the Bar X, major trees include: Maple, mountain willow, cottonwood, sycamore, walnut and ash.

For the most part, riparian species require more water than normal precipitation can provide (Ffolliott & Thorud,1974). Consequently, these species are usually found only along stream courses and lakes.

Figure 19. The vegetation in this area has been grazed to the point that it is no longer capable of holding the soil in place. The net result has been severe sheet erosion. Note how this process removes the productive topsoil and leaves the heavier rocks on site.

Figure 20. Evidence of active sheet erosion includes the deposition of sediment behind logs and other obstacles.

Figure 21. Severe gully erosion is evident throughout the pinyon-juniper vegetative community. As this photograph indicates, these gullies are currently very active--channel banks are raw, channel bottoms are "V" shaped, and the beginning or "heads" are moving upslope.

Figure 22. This photograph was taken from the bottom of an old gully in the Pine Creek Study Plots. Notice how the herbaceous vegetation is stabilizing the soil, and how the channel sides and bottom have become rounded.

The requirement that these species have for a readily available water supply also implies that they use a considerable amount of moisture. This has proven to be the case in numerous research studies designed to quantify transpiration losses (evaporation from plants) from riparian species.

It is important to realize that riparian areas are not unstable, temporary biotic communities (Lowe, 1964). To the contrary, they are extremely diverse, stable and productive. As a result, they are highly valued as habitat for many species of wildlife. In addition, riparian areas are attractive for camping, picnicking, fishing and numerous other recreational activities. These communities are also extremely important from a hydrologic point of view as many activities occurring within them have a direct and immediate impact on the adjacent aquatic environment.

Findings

The abundant food, water, shade and gentle terrain normally found in riparian areas provide a particularly favorable environment for domestic livestock. Consequently, cattle and sheep tend to concentrate in these areas.

All of the riparian areas examined on the Bar X allotment showed signs of extremely heavy grazing pressures. This included portions of Gordon Canyon, Colcord Canyon, Naegelin Canyon, Haigler Canyon and numerous other areas adjacent to smaller tributaries. Grasses and other herbaceous cover in these areas have been grazed to the ground. In some locations, the soil is totally devoid of understory vegetation (Figure 23).

The maintenance of good vegetative ground cover is particularly important in the riparian community as:

1) Good ground cover acts as a filter by slowing surface runoff and stopping appreciable quantities of debris and sediment before they reach watercourses (This filtering effect has been recognized for some time and it is now a common practice to utilize undisturbed "buffer strips" to protect watercourses from logging activities, road construction, etc.).

2) Vegetation holds the stream banks in place (Soil and other loose material forming stream banks are extremely susceptible to the erosive forces of flowing water without live plant roots to hold them in place).

Figure 23. Vegetative ground cover near Haigler Creek is virtually absent in some areas. In this particular case, the lack of vegetation can be attributed to both livestock grazing and recreational use.

Figure 24. Pine Creek has unstable stream banks, and erosion will soon claim the juniper tree that once grew on firm ground.

The lack of vegetative ground cover in the riparian community on the Bar X Allotment has resulted in the usual and predictable consequence--erosion. This erosion is occurring primarily from bare areas within the flood plain, including the stream banks themselves.

Eroding stream banks are prevalent on the Bar X (Figure 24). They are not only a result of inadequate vegetation to stabilize the banks, but of the increased peak storm flows that typify overgrazed lands. As previously discussed, these peak storm flows apply greater erosional forces to the stream banks than do peak storm flows from areas being properly managed.

Much of the material that is eroding from the riparian community washes directly into adjacent watercourses. This material, along with sediment from other areas of the watershed, is present in the streams of the Bar X in excessive quantities. This is evident from examining stream bottoms where large amounts of sediment have accumulated (Figure 25). It is also apparent during rainstorms (including light intensity frontal storms) when the streams turn a muddy brown color (Figure 26).

This sediment and debris is degrading the aquatic environment. More specifically, according to McKee and Wolf (1963), material suspended in water

> " .... may kill fish and shellfish by causing abrasive injuries; by clogging the gills and respiratory passages of various aquatic fauna; and by blanketing the stream bottom, killing eggs, young, and food organisms, and destroying spawning beds (3660). Indirectly, suspended solids are inimical to aquatic life because they screen out light (see Turbidity) and because, by carrying down and trapping bacteria and decomposing organic wastes on the bottom, they promote and maintain the development of noxious conditions and oxygen depletion, killing fish, shellfish and fish food organisms, and reducing the recreational value of the water."

Figure 25. As can be noted in this photograph of Colcord Creek, the accumulation of sediment on the channel bottom is excessive. Also notice the raw channel banks.

Figure 26. The headwaters of Gordon Creek during a light intensity rainstorm. The large amount of sediment in this creek is not typical of a high mountain watershed in good condition.

DISCUSSION AND CONCLUSIONS

One of the primary purposes for originally establishing the Tonto National Forest was for watershed protection. This is evident from reviewing some of the reports written by early day investigators such as S. J. Holsinger. In 1904, Holsinger rode over much of the present day forest and subsequently wrote: "These mountains [Mazatzals] form a large portion of the watershed of Tonto Creek and it would seem advisable to protect them in every possible way in order to prevent silting of the great Tonto Reservoir [Theodore Roosevelt Lake], now under the process of construction." Similarly, in 1914 Regional Forester Arthur C. Ringland wrote, "Clearly the principle value of the Tonto Forest is for watershed protection." Protecting the water and soil resources is even more critical today than it was at the turn of the century. With the tremendous demand for renewable natural resources, maintaining the soil in a productive condition is of paramount importance. Similarly, the necessity of providing good quality water for downstream aquatic life and human use cannot be overstated. Water derived from the Tonto is a major source of supply for the 1.4 million people in the Phoenix metropolitan area. This water is used for domestic, agricultural, industrial, recreational and wildlife purposes.

Recognizing the importance of water and soil resources on the Tonto, their protection and improvement was recently made the number one priority goal on the Forest (Tonto National Forest, 1977). This goal is consistent with national policy direction which states that "Management activities of other resources must, in turn, protect the basic soil, water, and geology resources" (U. S. Forest Service, 1976). More importantly, this goal reemphasizes the need for protecting two of the most basic and necessary resources on earth.

After reviewing the Bar X allotment, it is obvious that we have not been meeting our resource management objectives. That is, we are not protecting nevertheless improving the soil and water resources. To the contrary, erosion and water pollution are prevalent.

The pinyon-juniper and riparian vegetative communities are suffering the worse damage. Soil loss in the form of sheet and gully erosion in the pinyon-juniper community is severe. These losses far exceed those that occur as a result of natural geologic processes. This is evident from examining protected areas such as the Pine Creek Study Plots which have healed considerably since exclusion of domestic livestock.

The riparian areas on the Bar X are currently in a deteriorated condition. The damage in these areas is of two types. First, the land itself does not have adequate vegetative ground cover and erosion is occurring. Secondly, the sediment from deteriorated lands upstream is degrading the aquatic environment.

In terms of ability to produce forage, the pinyon-juniper and riparian communities are far and away the most productive on the Bar X. Yet, the overuse of these areas and resultant loss of topsoil has and will continue to reduce their productive capability (Figure 27). With this continued loss of available forage, more grazing pressure will be placed on the other remaining areas of the allotment. Thus, without action aimed at balancing the forage resource (supply) with livestock use (demand), vegetation, soil, and water resources will continue to deteriorate.

There is a close relationship between precipitation and forage production. Thus, a severe drought could result in poor range conditions. An examination of the U. S. Weather Bureau records at Young, Arizona over the past ten years shows yearlong precipitation to be only 5% below the long-term average. These records also indicate that precipitation has been above normal during four of the last ten years. When considering the last two years, precipitation during the winter-spring (January-April) and summer (July-September) growing seasons has been 108 and 119% of the long-term average, respectively. Thus, while precipitation has been below average at various times during the past ten years, we cannot attribute the poor condition of the range to lack of adequate moisture. Certainly, the massive soil losses that have been occurring in this area for many years indicate that the problems on the Bar X cannot be explained by a short-term drought.

Precipitation will always vary greatly from year to year. Thus, years of below average moisture and forage production can be expected. This fact must be recognized and planned for in resource management or as stated by Stoddart, Smith and Box (1975):

> "This marked reduction in forage yield resulting from poor growing conditions alone makes it evident that no plans for grazing should be made without allowing for variation in production attributable to weather conditions..... The plant resource and grazing animals must be in balance at all times. If there is to be a temporary imbalance, it should be in favor of the plant, rather than the animal, if long-term production is the manager's goal .... Forage remaining in years of high production is not wasted, for it adds to the vigor of the plants, permitting them to recover better from close use during poor years."

It should be noted that some of man's other activities on the Bar X allotment also affect the water and soil resources. In fact, any activity which removes the vegetative ground cover and compacts the soil surface will increase the potential for erosion. Road construction, fuelwood cutting, commercial timber harvesting and recreational uses are activities on the Bar X that contribute to erosion and sedimentation. Any resource management problems associated with these activities, however, do not alleviate the need to correct grazing problems. In addition, it is obvious from examining the rangelands that grazing is removing the bulk of the vegetative ground cover--not roads, timber harvesting or recreational activities.

Figure 27. Excessive livestock grazing has resulted in erosion, which will affect the capability of the Bar X allotment to produce forage for years to come.

The inescapable conclusion is that domestic livestock grazing is causing excessive soil erosion and sedimentation on a significant portion of the Bar X allotment. In order to alleviate this problem, grazing use must be brought into line with the inherent long-term capability of the land to produce forage. Only in this manner will adequate vegetative ground cover be available to protect the soil and water resources.

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APPENDIX A

Precipitation Data

A. Young, Arizona (Pleasant Valley)

Precipitation (inches)

Year	January Thru April	% of Long-Term Average	July Thru September	% of Long-Term Average	Year-Long	% of Long-Term Average
1968	5.76	98	6.18	77	16.77	87
1969	6.42	109	7.03	88	20.48	106
1970	3.89	66	9.38	117	15.45	80
1971	1.21	21	10.44	130	18.66	96
1972	0	0	4.85	60	21.96(E)	113
1973	10.09	171	3.61	45	17.56(E)	91
1974	5.47 (E)	93	5.84	73	16.99(E)	88
1975	6.13	104	3.95	49	14.35	74
1976	7.35	125	8.97	112	19.90	103
1977	5.36	91	10.15	126	16.51*	111*
10 Yr. Average	5.17	88	7.04	88	17.86	95
Long-Term Average 1941-1970	5.89		8.03		19.37	

*Based on January Through September, 1977

(E) Amount is partially estimated.

B. Colcord Estates

Year	Precipitation (inches)
1971	29.1
1972	31.1
1973	29.1
1974	25.5
1975	27.6
1976	29.8

APPENDIX B

Statistical Data for Soil Tests

Near the Pine Creek Study Plots

Statistical test to determine if penetrometer readings inside the study plots (ungrazed) are different from those taken outside of the plots (grazed).

Data:

	Outside (1)	Inside (2)
$\bar{X}$	2.29	1.57
s	1.60	1.23
EX	457.35	313.95
EX^2	1554.71	794.94
n	200	200

1) Test to see if the variances of the two population groups differ.

$$F = \frac{S_1^2}{S_2^2}$$

$$F = \frac{1.60^2}{1.23^2} = 1.69$$

1.69 is greater than tabulated F at the 1% level of significance, thus variances differ.

2) Student's t Test

$$t^1 = \frac{\bar{X}_1 - \bar{X}_2}{s_{\bar{d}}}$$

$$s_{\bar{d}} \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

$$s_{\bar{d}} = \sqrt{\frac{(1.6)^2}{200} + \frac{(1.23)^2}{200}}$$

$$= 0.143$$

$$t^1 = \frac{2.29 - 1.57}{0.143}$$

$$= 5.03^{**}$$

As $n_1 = n_2$ we can compare this value with a tabulated t value in the book t .01 = 2.6

As 5.03 is greater than 2.6, the difference between means is statistically significant.

APPENDIX C

Surface Runoff and Peak Flow Calculations

Soil Conservation Service Method

1. Surface Runoff

Input
Design Storm 10 yr. - 1 hr. = 1.4 inches from map

Antecedent Moisture Conditions: Class II

Soil Group: D

Vegetative Type: Pinyon Juniper - Grassland

Vegetative Ground Cover Density:

a) Outside of Pine Creek Study Plots - 20%
b) Inside Pine Creek Study Plots - 46%

Based on the above data, a runoff curve number was selected from SCS Handbook.

Curve Number for 20% density = 91 or S = 0.989
Curve Number for 46% density = 88 or S = 1.36

Calculations

$$Q = \frac{(P - .2S)^2}{P + .8S}$$

Where: Q = Surface Runoff
P = Precipitation
S = Potential maximum rainfall retained plus initial abstraction

Case 1. 20% Vegetative Ground Cover

$$Q = \frac{[1.4 - (.2)\ (.989)]^2}{1.4 + (.8)\ (.989)}$$

Q = 0.66 inches

Case 2. 46% Vegetative Ground Cover

$$Q = \frac{[1.4 - (.2)\ (1.36)]^2}{1.4 + (.8)\ (1.36)}$$

Q = 0.51 inches

2. Peak Flow

Input

Watershed Area: 2.9 miles square

Storm Duration: 1 hour

Length of Primary Streamcourse: 16,632 feet

Change in Elevation of Watershed: 1,090 feet

Calculations

$$qp = \frac{484\ AQ}{\frac{\Delta D}{2} + .6Tc}$$

$$Tc = \frac{L^{1.15}}{7700\ H^{.38}}$$

Where: qp = Peak Flow
A = Watershed Area
Q = Surface Runoff
D = Storm Duration
Tc = Time of Concentration
L = Length of Primary Streamcourse
H = Change in Elevation of Watershed

$$Tc = \frac{(16{,}632)^{1.15}}{7700\ (1090)^{.38}}$$

Tc = .65 hrs.

Case 1

20% Vegetative Ground Cover

$$qp = \frac{484\ (2.9)(.66)}{.5 + (.6)(.65)}$$

qp = 1040 cubic feet per second (cfs)

Case 2

46% Vegetative Ground Cover

$$qp = \frac{484\ (2.9)(.51)}{.5 + (.6)(.65)}$$

qp = 805 cfs