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Rangeland Management and Hydrology

K. Wood
New Mexico State University

H. Rubio
National Research in Forestry, Agricultural and Animal Production, Mexico

C. Wood
Utah Division of Wildlife Resources

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Rangeland management and hydrology

K .Wood[1] , H .Rubio[2] , and C .Wood[3]
[1] Director , Water Resources Research Institute , New Mexico State University , Las Cruces , NM 88003 USA , E-mail : kwood @wrri .nmsu .edu ; [2] Researcher .National Research in Forestry , Agricultural and Animal Production , Chihuahua , Mexico ; and Habitat Manager , Southeastern Region , Utah Division of Wildlife Resources , Price , Utah 84501 USA

Key points : Rangeland improvements have included techniques to manipulate the hydrologic cycle on rangelands . Grazing practices have been designed to minimize soil erosion and maximize water use by plants .

Key words : Runoff , erosion , infiltration rate , watershed , water harvesting , grazing management , range improvement techniques

An early range saying was , It takes more than the twinkle in a bull's eye to produce cattle on the western range ." This referred to the western U .S .A .but probably applied to most rangelands of the world . Indeed the entire rangeland ecosystem needs to be understood to raise cattle and the many other rangeland products and services . An important part of rangeland ecosystems is the hydrologic cycle as water is the fluid of all life . This paper examines the historical perspective of rangeland developments and improvements as they relate to the hydrologic cycle with most emphasis being a North American perspective .

Early hydrology research

Hydrology has its roots as a science with ancient civilizations . There is evidence of canals , aqueducts and irrigation infrastructure that existed about 3 ,500 BC . The phoenicians constructed rock-wall terraces to hold the soil after they cut the Lebanon cedar forests . Vitruvius , centuries later , believed in the pluvial origin of springs and Palissy (1510-1590) stated categorically that rainfall was the only source of springs and rivers . In the 17th century , Pierre Perrault and Edmé Mariotte of France and Edmund Halley of Great Britain undertook hydrological research of modern scientific type so that they may well be regarded as the founders of hydrology . The 18th century saw the beginnings of systematic river flow measurements on several continents . In the 19th century , William Smith in England connected geology with groundwater , and Darcy laid the foundation of groundwater theory . Enormous advances in hydrology were made during the 20th century , especially in conservation ; irrigation ; flood control ; remote sensing ; and ground , surface , and atmospheric modeling . Scientific advances continue into the 21st century .

Early range research

In contrast , range science is less than 100 years old , originating during the 1930's as a discipline offering university degrees . The need for systematic methods of rangeland assessment first became apparent when Jared Smith was sent by the U .S . Botanical Survey in 1895 to study the causes of the deterioration of western U .S .A .rangelands that had been widely reported in the late 1880s . Many range research methods and techniques have been developed at a rapid rate since the 1930's . The first textbook in hydrology was Nathaniel Beardmore's *Manual of Hydrology* published in 1862 . The first textbook called *Range Research-Basic Problems and Techniques* was published a hundred years later in 1962 .

Bringing hydrology and range research together

Hydrology and range science came together following flooding from overgrazed alpine areas of the Wasatch Mountain in Utah , USA . Research led to changing the kind and number of livestock using the watersheds . Hence , runoff and erosion studies began on rangelands in the U .S .A .before those on croplands (Columbia , Missouri in 1917) and forestlands (Wagon Wheel Gap in Colorado in 1910) and at locations farther west . Grazing studies in relation to watershed management , initiated in 1920 on the Tonto National Forest in Arizona U .S .A . , helped lay the foundation for recognition of the value of such studies in western watershed management . Studies on erosion and flood problems in California included consideration of grazing of rangelands .

When considering the many hydrologic-related perturbations that may be applied to the various combinations of plants , soils , and climates , it is obvious that the hundreds of publications on rangeland watershed management are really insignificant in describing the effects of upland treatments on water yields , sediment yields , and dissolved solids in runoff .On rangelands , treatment effects over many years are difficult to separate from the effects of natural climatic fluctuations during the same years .Both watershed and plot studies are required to provide this information .Watershed studies on most rangelands are characteristically long term .If two gauged watersheds are being compared , twenty-five to thirty runoff events are often needed for calibration before one watershed is treated .These twenty-five to thirty runoff events may not occur for many years .Gauging equipment is quite expensive . Homogeneous watersheds are often difficult to locate for pairing . Finding three or four homogeneous watersheds is often impossible—therefore , small , unreplicated samples are often used .After several more years of evaluating treatment effects , too few publications usually came from these large , long-term investments ; thus , plot studies have been very popular in the past 50 years for evaluating watershed variables .

One of the pioneers of small rangeland watershed plot studies was Frank Rauzi in the 1950s in the northern Great Plains of the U .S .A . Simulated rainfall was applied to small plots to measure infiltration rates and sediment yield in various plant-soil complexes under various management schemes .This type of research had been conducted by other researchers since the 1930s , but Rauzi applied the techniques widely under numerous conditions .His publications are referenced in most of the Literature Cited Sections" of infiltration publications today .

Post-world war II range improvement practices

Since World War II , rangeland watershed research and application have had a two facet approach .Cheap energy allowed drastic mechanical range improvement practices to be applied to vast areas of western rangeland .A principal goal of many of these practices was increased infiltration rates , which reduced runoff and erosion .These continued until 1973 , when increased energy prices allowed these practices to be used only on rangelands with high potential for forage response or special areas , such as mine tailings or highways and roadways .Range improvement practices since 1973 have had to depend on favorable responses coming during an extended period of time .This has also been an experimental period , with many modeling and prediction efforts and with many environmental concerns being voiced . Watershed researchers have found that hydrologic condition is generally correlated with range condition and seral stage .As a range site experienced plant succession from parent material through the stages of soil development to climax , the infiltration rates increased and sediment production decreased . A retrogressive influence caused an opposite reaction .Many grasslands and savannas were historically depleted of woody shrubs and trees by the occasional occurrence of wildfires .This so-called pyric disclimax condition was interrupted by overgrazing by livestock and by a very successful century-long fire prevention program .This resulted in vast areas of rangeland becoming infested with shrubs and trees , which produced a decrease in forage production .It was also found that infiltration rates increased and erosion and sediment production decreased directly under the shrub or tree in an area influenced by the plant′s crown .In the interspaces between plants , the understory disappeared from overgrazing and competition from the shrubs and trees .Unless the soils were very sandy , the interspaces became highly erosive , which led to rapid retrogression in seral change . Therefore , the range improvement practices that were used to kill brush and trees such as rootplowing and chaining , also improved hydrologic condition—if a successful stands of forage plants were established .

Several range improvement practices were used solely to increase infiltration of the surface water .Contour trenching was used from the beginning of the 20th century through the 1960s .The trenches were most often built in alpine areas above the timber line and were 1 to 2 meters deep .The objective was to contain all water and sediment on-site .Costs were very high and had to be justified by the benefits to downstream wildlife and human inhabitants , through changes in quantity , quality and regimen control of runoff and ground flow .Rarely did the trenches increase forage production on-site because less productive soil from the subhorizons was piled on top of the topsoil during construction . Contour furrows were made extensively on rangelands prior to the increased energy prices of 1973 .The furrows were 1 .5 meters apart , 20 to 30 centimeters deep , and 50 to 75 centimeters wide .The capacity of the furrows exceeded 50 mm of precipitation , with an expected life effectiveness of about 10 years . However , a rather questionable benefit-cost ratio was derived .

Pitting on rangelands consists of forming with a notched disc on plows small basins that are commonly 1 to 2 m long , 20 to 30 cm wide , and 10 to 20 cm deep .Another type of pitter has a series of spike teeth on a rotary drum .The teeth punch holes in the soil surface that are narrow and about 22 cm deep , spaced about 1 m apart .The spike tooth pitters have generally failed , while the disc pitters have been used in the Great Plains of the U .S .A .for increased production of established plants and in the southwestern U .S .A .for establishment of grass seedlings . A technique related to pitting is a land imprinter that consists of a steel drum with angle irons welded to it that imprints a variety of geometric patterns on the soil surface . Infiltration increases with a reduction in runoff and evaporation , while water is routed to the plant roots .

Ripping to a depth of 1 m is used to break compacted soil profile layers that inhibit soil moisture penetration and root development .A large energy-consuming bulldozer is required .Results have been quite variable . For untreated soils in New Mexico , U .S .A .surface runoff was as high as 89 percent of storm rainfall ; annual erosion , as high as 4 ,640 kg per hectare . Ripping reduced runoff 96 percent and erosion 85 percent in the first year after treatment .Three years after treatment , the reductions amounted to 85 percent for runoff and 31 percent for erosion .

Waterspreading on rangeland involved diverting water from stream channels and distributing it over nearby flood plains or valley floor with a dam and a series of dikes .It can also involve the spreading of runoff water and decreasing its velocity to maximize infiltration before the water reaches a channel .Operation is mostly automatic whenever sudden , torrential storms result in overland flows .These systems of water conservation are often in conflict with water laws .Many of these systems have been very elaborate in the past , combining spreading dikes , respreading dikes , contour furrows , gully plugs , and check dams .A more recent dike arrangement consists of a series of crescent or horseshoe-shaped dikes with water spilling around the ends .Dikes are located such that water from one dike spills into another dike downslope .The freeboard was only 30 cm high and easily and quickly constructed with a motorized road grader .Soil moisture was increased from 15 to 40 percent in the top 60 cm of soil .

Specialized water harvesting techniques

A specialized area of rangeland watershed research and development since World War II has been water harvesting .This process involves collecting and storing water from land that has been treated to increase runoff .Many examples of water harvesting techniques have been used by ranchers , municipalities , and federal agencies for watering domestic livestock , municipal purposes , and wildlife .These developments have been given various names including guzzlers , trick tanks , paved drainage basins , catchment basins , and rain traps .Nearly all designs have a water-collection area or apron , a storage tank , and a watering trough .Size varies from a few square meters to thousands of hectares .The small designs are used for watering small animals such as upland game birds .An example of water harvesting for a municipality is the city of San Angelo , Texas , U .S . A .which depends on surface runoff to supply municipal needs .Large reservoirs were constructed adjacent to the city ; but in the mid 1970s they were nearly empty from drought .City officials inquired about techniques to increase runoff from the collection area that was covered by a mesquite (*Prosopis* sp .-short grass community .Controlling the brush increased runoff and decreased evapotranspiration rates . Grazing the shortgrass increased the runoff but fecal material , at some level of concentration , would be added to the runoff . If overgrazing occurred , excessive sediment was suspended in the runoff .The problem was at least temporarily solved by brush control and an end of the drought . Other methods of water harvesting include : water collection form naturally impermeable areas such as slick rocks ; treating the soil with chemicals so that they become impermeable ; and covering porous soils with corrugated roofing , plastic sheets , aluminum sheets , or heavy roofing materials .Although initial costs and maintenance demands are great , water harvesting may be the only practical method of developing water in certain areas .In many areas , these techniques do not require water rights .They may be less expensive than hauling water and at the same time minimize energy demands and water pollution problems .

Hydrologic implications of grazing management

The hydrologic effects of ungulate grazing were first considered in the 1970's . Grazing schemes use one to several herds in one to many pastures or paddocks were being tried and investigated in many areas . At the 1st International Rangeland Congress in Denver , Colorado , USA in 1978 , Alan Savory introduced his grazing methods that often consisted of many paddocks (up to 50) , one herd , and very short grazing periods in each paddock (1-3 days) . Extensive research followed in many countries including the United States , Mexico , Australia , and Pakistan . Some general statements can be made from this research concerning domestic and wild ungulates as their presence relates to water in the ecosystem . Grazing reduces plant cover and volume , and plant species respond differently to grazing . Some plant species have little resistance to grazing while others have great resistance , and still others are stimulated by grazing . The number of plant species that are stimulated by grazing is not near as great as claims by advocates in the 1970's . Some plant species with little resistance to grazing may become more resistant with subsequent generations . And some species such as blue grama (*Bouteloua gracilis*) may have a bunchgrass form under moderate to no grazing , but change to a sodgrass with lower production under heavy grazing which results in more runoff and erosion . Reduced plant cover and volume result in decreased interception of precipitation and decreased transpiration by plants . Decreased plant cover and volume also result in decreased organic matter additions to soil , which affects soil structure and porosity . Additionally , water infiltration rates decrease , and runoff and erosion increase . Increased runoff and erosion lead to loss of sustainability after about 50% utilization of the present year's plant growth .

Hoof action (often called trampling) by ungulates also reduces plant cover and volume with the same effects on the hydrology as grazing . Trampling has been touted as a great beneficiary to soils by causing the same beneficial effects as mechanical plowing . In reality , trampling increases surface roughness when the soils are wet resulting in decreased runoff and erosion . Trampling decreases soils roughness when soils are dry resulting in increased runoff and erosion . Unfortunately , most arid and semi-arid rangelands are usually dry . Trampling also affects soil configuration known as trails . When they are found up and down slopes , runoff and erosion increase . When they are found across slopes , runoff and erosion decrease . Trampling decreases bulk density and porosity which results in increased runoff and erosion . Fortunately , annual increases in bulk density are often mitigated by cold-weather freeze-and-thaw conditions . So what are the benefits of trampling other than increasing roughness in wet soils ? In loose sandy soils , trampling can increase bulk densities which results in increased water holding capacity . This allows water access to plants that may be increased from a day to several days , which is enough for considerably more plant growth . Trampling can also control soil-dwelling animals such as rodents whose exposed mounds result in high erosion rates . A study in Colorado , USA showed that pocket gophers may add up to 12 .5 metric tons ha^{-1} yr^{-1} of sediment to streams . A diagram showing how rangeland management practices affect plant and rock cover ; plant volume ; and animal grazing , trampling , and burrowing , which ultimately affect runoff and erosion is shown in Figure 1 .

The benefits of dung and urine added to soil surfaces have been known for millennia . Since the early days of environmental awareness , there has been concern of dung being washed by runoff into streams . Because of its nature to solidify shortly after deposit , dung is not readily washed into streams by runoff unless it is deposited onto bare ground that is connected to a runoff system or the defecating animal is in the stream . Fisheries in watershed of low fertility may benefit from accelerated erosion and elevated nutrient levels .

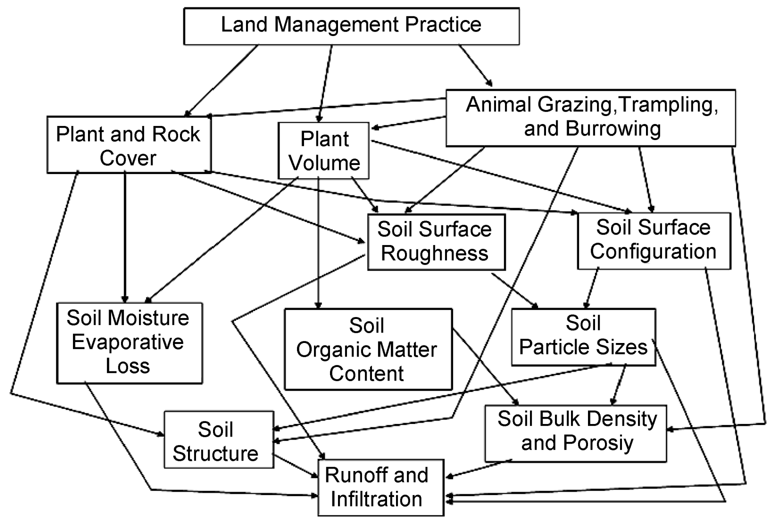

Figure 1 *Diagram showing how land management practices affect runoff and infiltration.*

It is also noted that it is easy to fence out livestock. It is difficult to fence out wildlife, so the total number of ungulates may not change from fencing out livestock. Stocking rates that result in 0% to around 50% utilization of the current year's plant growth are usually sustainable. Stocking rates that are much greater than 50% utilization of plants are rarely sustainable from a hydrologic point of view. This applies to grazing schemes that use all the forage in a pasture or paddock, even if they rest it for long periods of time following grazing.

Generally, those grazing schemes that improve vegetation conditions also improve soil and hydrologic conditions. It is possible to increase forage without damaging other rangeland uses. It is not known how to do this in all areas of the world.

Conclusions

From a hydrologic point of view, most rangelands can be sustainably grazed by livestock and other ungulates. Grazing levels and rotation schemes need to be tailored to each individual ranch or pasture. Past abuses can be mitigated with numerous mechanical and biological techniques beyond grazing manipulation. Affordability and time constraints challenge range managers to be creative and use various techniques to achieve long-range goals. Hydrologic considerations should not be overlooked, and many management practices can be used in reaching those goals.