Producing, Conserving, and Sustaining Natural Resources: the Role of Watershed Management

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ABSTRACT

A diversity of benefits to local watershed inhabitants and a greater number of people within the larger river basin is obtained through the flow of water and other natural resources off of upland watersheds. Because these watersheds are the headwaters of many of the rivers in dryland regions, proper watershed management is a prerequisite to sustaining the flows of high-quality water necessary to people. Forage, food, and fiber found on watersheds should also be managed in the most economically efficient and environmentally sound combinations to obtain the products, commodities, and amenities that people need. We present a holistically conceived watershed management approach to land stewardship that is oriented toward producing, conserving, and sustaining the natural resources that can realistically be obtained on watersheds in arid and semi-arid environments.

INTRODUCTION

Producing, conserving and sustaining natural resources have historically been a concern of people living in the dryland regions of the world because of the often encountered “marginality” of availability of these resources. Water scarcity and the availability of other natural resources are likely more critical to a greater number of people living in dryland regions than those inhabiting the more humid regions of the world. According to a report prepared by the Dialogue on Water, Food and Environment, a consortium of international organizations concerned with the status of world’s water resources, about 2.7 billion people, or nearly one-third of the world’s population, will live in regions of acute water scarcity by 2025. The people of southern Asia and sub-Saharan Africa will be the most severely affected. Water will always in a crucial balance in arid and semi-arid environments and this balance is being upset at alarming rates over large areas by people and their land-use practices. These trends can be reversed through well conceived watershed management and better land stewardship. However, there are differing views about what watershed management means. We present a perspective of watershed management that is oriented toward producing, sustaining, and conserving soil, water, and other natural resource benefits that can realistically be obtained by people in arid and semi-arid environments. Further details on these and related topics are elaborated upon in Ffolliott et al. (2002).

MEANING OF WATERSHED MANAGEMENT

The meaning of watershed management that is used in this paper is based largely on the definitions and concepts of Brooks et al. (1992, 1994, 1997), Gregersen et al. (1987, 1996), and the National Research Council (1999) of the United States. *Watershed management* is the process of organizing the use of natural resources on a watershed to provide necessary goods and services to people, while mitigating the detrimental impacts of land-use activities on soil and water resources. This approach recognizes the intrinsic interrelationships among soil, water, and land

use and the connections between upland watersheds and larger downstream river basins. It incorporates soil and water conservation and land-use planning into a more holistic and logical framework. This more encompassing approach to land stewardship is achieved by recognizing both the positive and negative impacts on people that are caused by planned or unplanned interactions of soil and water with other natural resources.

It is also necessary to appreciate that the nature and severity of these interactions are influenced by how people use these resources and the quantities of resources that they use. The effects of these interactions are more likely to follow watershed than political boundaries. Watershed management activities on the uplands of one political unit can significantly impact on the well-being of people living on a downstream political unit regardless of the respective land ownership, often resulting in unacceptable downstream or off-site effects. A *watershed management approach* to land stewardship accommodates the interests of the widest possible number of people. The approach examines the benefits obtained from good land stewardship by optimizing production and maintaining environmental integrity. It facilitates more effective conflict resolution from a sustainability perspective. A watershed management approach further recognizes that future generations of people deserve to inherit landscapes that are capable of producing the needed goods and services while maintaining ecosystem health and economic stability.

PRODUCING, CONSERVING, AND SUSTAINING NATURAL RESOURCES

Watersheds provide a diversity of benefits to local inhabitants and to a greater number of people within the larger river basin through the flows of water and other natural resources off the watersheds. Inhabitants of watersheds manage their lands for the production, conservation, and sustainability of forage, food, and fiber that they require to survive and generate income. Therefore, water, forage, wood, and other natural resources on the watersheds should be managed in the most economically efficient and environmental sound combinations possible to obtain the products, commodities, and amenities that the people need. The consumption or otherwise use of the natural resources on upland watersheds must also be balanced with the needs of people living downstream and the larger river basin. Upland watersheds are the headwaters of many large rivers in dryland regions. As a consequence, the proper management of upland watersheds is prerequisite to sustaining the flow of water that is necessary to maintain agricultural production within larger river basins. How these watersheds are managed is crucial to sustaining the flows of other commodities and amenities that are necessary to the livelihood of the people living on the watersheds and to downstream residents.

High Quality Water

Water limits much of what people can do. Sustainability of high quality water supplies is critical to the welfare and, ultimately, the survival of people living in dryland environments. It should not surprising, therefore, that the emphasis of watershed management practices in drylands is placed on developing and conserving supplies of water for both upland and downstream uses. Fortunately, numerous methods are used in developing water supplies in the absence of perennial streams or abundant groundwater (Brooks et al. 1997). Water harvesting is one example. Water harvesting systems involving the collection and storage of rainfall until the collected water can be beneficially utilized have been used to provide water for livestock production, forestry activities, or agricultural cropping for over 4,000 years in many dryland regions of the world. Interest in this technology continues to the present. Likewise, water spreading is a proven method of distributing intermittent water flows onto a landscape to enhance forage and crop production. Water harvesting and water spreading methodologies are used to both increase water supplies and productivity of the land that reduces the pressures of overgrazing by livestock, deforestation, and improper agricultural cultivation.

Water that is captured during periods of abundance can often be conserved for use at a later time through methods that reduce evaporation, transpiration, and seepage losses. Methods of reducing evaporation from stock tanks and other small impoundments include covering these water bodies with polystyrene, rubber sheeting, or floating blocks of wax. Aliphatic alcohols and other liquid chemicals that form monomolecular layers on the water surface have also been used to reduce evaporation on larger water bodies. Transpiration losses are reduced by replacing plant species that have high transpiration losses with species that have lower transpiration rates; removing plants with deep rooting systems that extract water from shallow water tables; and applying antitranspirants that either close stomata or form a film on leaf surfaces. Methods of reducing seepage losses from small reservoirs and earthen canals constructed in pervious soils include the compaction of the soil within these structures; the treatment of the soil surface with chemicals to break up aggregates; and lining the canals and bottoms of the reservoirs with impervious materials. This latter method can be too expensive for application on large reservoirs, however.

There can be adequate water to meet local needs in some instances, but its quality might be such that it is not suitable for its designated uses. Available water supplies, therefore, must be considered in the context of water that is suitable for a designated use. The quality of water flowing from upland watersheds is affected by geological-soil-plant-atmospheric systems and land uses. Water flowing from watersheds that are maintained in a good condition is usually high in its physical, chemical, and biological quality and, therefore, suitable to a wide array of designated uses. The reverse situation is the case when watersheds are in poor condition. *Watershed condition* is a term that indicates the health (status) of a watershed relative to its ability to process rainfall into streamflow and the watershed's capacity for sustaining plant growth (Brooks et al. 1997). Watershed management practices that maintain a watershed in good condition are those that sustain high rates of infiltration into the soil; do not contribute to excessive soil erosion; facilitate a relatively slow streamflow response to inputs of precipitation; and sustain baseflow between precipitation events on perennial stream systems.

Because evapotranspiration accounts for much of the disposition of precipitation falling on watersheds, vegetative changes that reduce evapotranspiration rates generally increase water flows from a watershed. Evapotranspiration is reduced by changes in the composition and structure of the vegetative cover on the watershed. Watershed studies worldwide have shown that water flows can be increased from 5 to 650 mm of pretreatment streamflow regimes when vegetation is converted from deep-rooted plant species to shallow-rooted species; a vegetative cover is changed from plant species with high interception capacities to species with lower interception capacities; or plant species with high transpiration losses are replaced by species with low transpiration losses (Bosch and Hewlett 1982, Whitehead and Robinson 1993). However, increases of water flows from vegetation manipulations in dryland regions are at the lower range of the above reported increases. About 480 mm of annual precipitation is required for vegetation manipulations to cause a significant increase in water flows in the western United States (Hibbert 1979). Precipitation below this minimal amount is effectively used by the residual forest overstory and subsequent increases in herbaceous plant cover on the watersheds. The length of time into the future that water flows continue to exceed pre-treatment levels is influenced by the type of vegetation that regrows on the treated watershed and the rate of this regrowth.

Livestock Production

Maintaining livestock is a traditional way-of-life of many rural societies that are indigenous to arid and semi-arid regions, and, therefore, implementation of proper livestock grazing practices on a watershed is necessary to sustaining livestock benefits. Dispersed livestock grazing on open rangelands or confined livestock grazing in small pasturelands or pens near homesteads is practiced. Many watersheds are able to sustain more than one type of ungulate, whether they are livestock or indigenous herbivores, with proper management of the lands that the animals graze.

The production of milk, meat, or wool for a marketplace and, therefrom, higher economic returns to pastorialists are often obtained by grazing more than one type of livestock (sheep, goats, cattle, etc.) or combining management of livestock and indigenous wildlife species. Inclusion of sheep or goats with cattle, while complicating the management procedures, can increase total livestock production without adversely impacting the availability of forage, fodder, and water resources on the watershed. In doing so, a better distribution of animals can also be achieved, resulting in a more uniform use of natural resources.

A key to concurrently sustaining livestock grazing and flows of high quality water is retaining a vegetative cover on the watershed. The production of native forage and fodder species and a presence of natural occurring water sources often meet these joint requirements on watersheds in good condition. On other watersheds, however, it might be necessary to remove undesirable (noxious) plants to favor the establishment and growth of more desirable forage species; improve forage and fodder production by seeding of species suitable to the conditions encountered; or develop additional water sources by drilling wells, constructing water harvesting systems. Building small impoundments to trap and hold runoff water that would otherwise be unavailable to livestock can also be necessary. Attaining the goal of sustainable livestock production requires that the area to be grazed be stocked only with the number of livestock that can be supported on a sustainable basis; that livestock grazing be permitted only during the proper (often rainy) season when adequate forage resources are available; that the livestock be distributed appropriately and not be allowed to concentrate along streams or other watering sites where they can cause increased soil erosion, sedimentation, or other pollution; and that the kind of livestock be stocked that are best suited to the condition of the watersheds. These managerial guidelines are necessary to sustaining a good condition of the watershed and preventing land degradation and, as a consequence, desertification.

Wood Production and Other Forestry Activities

Trees are a source of fuel, poles, and building materials for upland watershed inhabitants. The fruits, leaves, young shoots, and roots of trees also can be valuable food reserves for people in emergency situations. Trees are a source of fodder for livestock and browse for wildlife at times when herbaceous forage in not available. Trees can be planted in home gardens and parks, buffer strips along streets and sidewalks, and greenbelts around cities and villages to improve local environmental conditions. Trees play a vital role in maintaining the delicate ecological balance of arid and semi-arid environments. The roots of trees hold the often limited soil resources in place, control soil erosion, and help to stabilize steep slopes. Trees retained in windbreak plantings protect the site from accelerated aeolian erosion, lessen evapotranspiration rates, and moderate air temperature extremes. *Multipurpose tree species* are ideal for protecting and improving the fertility of soil while providing leaves and small branches for fodder without impairing agricultural cropping. Multipurpose trees often fix nitrogen in the soil in addition to providing benefits to local people and their livestock. The issue confronting managers is reconciling the needs of people living on the watersheds to harvest trees for fuel and other tree-based products with the ecological benefits obtain from the trees.

Trees in the woodlands and forests of the dryland regions of the world have often been mined more than managed as a *renewable* natural resource. Cutting of trees in excess of the sustainable production level in response to the growing needs of expanding human populations is likely to lead to a downward spiraling of available wood resources that is difficult to reverse. Converting woodlands and forests to livestock grazing lands or agricultural croplands compound this problem. Incidences of wildfire and inadequately controlled fire that is set by people in this conversion process are other contributing factors. Applications of appropriate forestry practices are necessary to remedy this situation.

Applications of management practices to sustain wood production and other tree-based benefits require a knowledge of the inherent reproductive, growth, and survival characteristics of the trees in question. This knowledge has not always been available in the dryland regions of the world. Customarily applied forestry methods and techniques developed in the more humid regions of the world do not necessarily apply in dryland regions because of the inherently limited reproductive capacities, slow growth rates, and low yields of wood of the trees in these ecosystems. Nevertheless, ecosystems containing trees must be properly managed in the context of a watershed management approach to land stewardship to maintain acceptable growing stock levels. Much as been accomplished in this regard in recent years (Ffolliott et al. 1995). Natural and artificial reproductive methods, intermediate cuttings to achieve optimal tree growth, applications of fertilizers, and other cultural treatments are being incorporated into holistic silvicultural systems that are applicable to woodlands and forests of many dryland ecosystems. Prevention, protection, and, when necessary, control measures against wildfire, disease, and insects are also known in many instances. People are recognizing the need to invest labor, time, and other resources in implementing these systems and measures. Increased knowledge of growth rates and yields of wood have allowed rotational periods and cutting cycles to be identified for the sustainable use of many tree species valued for fuel, poles, and other products. Importantly, the length of these periods must be reconciled with the immediate priorities of people to use the trees in sustainable watershed management programs.

Agricultural Cropping

Small-scale, mostly rain-fed, and dispersed agricultural cropping is another common land use on watersheds in dryland regions. While small in their individual contributions to the overall agricultural economy of a region, the aggregate production of all agricultural cropping on upland watersheds can be comparatively large (Ffolliott et al. 2002). Depending largely on the capacity of the land to produce agricultural crops and the level of capital available to do so, either *subsistence* or *commercial farming* might be practiced. The agricultural crops produced are utilized to meet the immediate needs of subsistence farmers, although the occasional surplus obtained might be sold at a local marketplace. Large scale commercial farming is less commonly found on upland watersheds because of the likely need for large-scale irrigation facilities, more diversified marketplaces, and costly infrastructures for the transportation of managerial inputs and production outputs

Small-scale farmers employ agricultural cropping systems that relate to the local climatological conditions, inherent soil capabilities, and their needs, abilities, and perceptions of agriculture in attempting to sustain themselves. While the agricultural cropping systems are endless in their strategies and methods of implementation, they can be grouped into categories of *settled agriculture* and *shifting cultivation* for discussion purposes. Settled agriculture is practiced where soil fertility and precipitation and temperature regimes allow crops to be grown in place on a more-or-less continuous basis. One crop a year is usually grown when rainfall amounts are sufficient. Shifting cultivation involves farmers moving from one site to another on a watershed once the potential of soil to produce agricultural crops at subsistence levels on the original site is lost. At higher elevations, cycles of shifting cultivation often include clearing of trees on the site, a burning of the residual vegetation with the ash serving as fertilizer, and planting of the agricultural crops. When soil fertility declines to the point of limiting acceptable crop production, the farmer moves to repeat the cycle elsewhere, eventually returning to the original piece of land. As populations of people and their livestock increase, the lengths of fallow diminish, soil losses increase, and productivity of the land declines.

Farmers often engage in agricultural cropping on watershed lands that could also be used to grow forage and fodder for livestock production or trees needed for fuel, other wood products. Potential conflicts in land use can be encountered when this is the situation. However, small-scale

agriculture can be compatible with watershed management objectives when it is practiced only on the sites suitable for agricultural cropping, considering both the land's inherent productivity potential and the economic returns of practicing agriculture on the land. One way by which sustained agricultural cropping is achieved on a watershed-basis is through a geographic separation of agriculture from other land uses with the other watershed strata put to the use or uses to which they are most suited. Another option is to alternate or rotate agricultural cropping with other land uses of a watershed being managed to maintain water flows, livestock production, etc. This option can evolve into a shifting cultivation system. A third option of achieving combined production, the concurrent and continuous use of a watershed for agricultural cropping, livestock production, forestry activities, and other land uses, is generally not feasible in the dryland regions of the world.

There are land use, vegetative, and engineering measures that are available to maintain or increase the productivity of watersheds in terms of environmentally-sound, small-scale agricultural cropping. Land use and vegetative measures include the establishment of windbreaks to protect sites vulnerable to excessive soil erosion and alley-cropping or other agroforestry schemes to optimize the site's productivity potentials and mitigate the risks of monocultures. Designating fallow periods of sufficient length of time to allow a recovery of the soil's fertility and, as a consequence, the land's productivity potential can be necessary. Engineering measures implemented for the same general purpose include the construction of bench or broad-based terraces, contour ditches, and gully control structures and protected waterways. Water harvesting, water spreading, and localized irrigation measures might also be considered.

Agroforestry Practices

Livestock grazing, forestry activities, and agricultural cropping often occur in varying combinations within a watershed boundary. Upland watersheds in many dryland regions are mosaics of these and other forms of land use. Some of the best opportunities for people to match their desired land uses with the capacities of a watershed to achieve productivity and benefits and, at the same time, attain downstream protection from flooding, sediment accumulations, and other detrimental and cumulative effects involve the integration of agroforestry practices into a watershed management approach to land stewardship. *Agroforestry* is a system of land use where trees or other woody plants are grown on the same piece of land as agricultural crops, livestock, or a combination thereof, either sequentially or simultaneously (Buck et al. 1999). As such, agroforestry practices are effective *combined production systems* and, therefore, have a bearing on sustaining the welfare of watershed inhabitants.

Agroforestry practices in dryland regions are mostly *agrsilvicultural, silvopastoral*, and *agrosilvipastora*l in their structure. Agrisilvicultural practices are combinations of agricultural crops and forestry activities with the agricultural crops dominating. Silvopastoral combinations are forestry activities and livestock production with a dominate land-use of forestry. Agrosilvipastoral practices include agricultural cropping, forestry, and livestock production in varying combinations of dominance. Arrangements of the components of agroforestry can differ in space (random, alternate rows, or border-tree planting) and time (coincident, concomitant, or sequential). Agroforestry practices also differ in their function, that is, whether they function to produce one or more of the commodity needs of people, ameliorate microclimates, retain soil and water resources, or combinations of these and other protective functions. Agroforestry practices are *subsistence*, *commercial*, or *intermediate* from a socioeconomic standpoint, depending on whether the outputs meet the basic needs of the people, are made available for sale at a marketplace, or a combination of the two.

CONCLUSIONS

Production, conservation, and sustainability of natural resources are constantly threatened by a possibility of improper human interventions degrading the capacity of a watershed to support local people's uses of the natural resources found on the watershed. Some degradation of a watershed can occur as a result of natural phenomena such as drought, landslides, or wildfire. Managers have little control over these events other than to maintain the best possible landscape conditions so that the impacted watersheds are able to withstand the consequences of these phenomena. But, even with what seems to be well-planned and environmentally sound land-use practices, the activities of people living in the dryland regions of the world can inadvertently worsen the sources of degradation and, in doing so, make then central issues in the management of a watershed. It is imperative, therefore, that the inhabitants of watershed lands adhere to the best possible form of land stewardship. A watershed management approach can greatly help in attaining this often elusive goal.

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