RANGE ECOSYSTEMS AS AFFECTED BY OVERGRAZING: A REVIEW

A. ARIF*
J. TIEDEMAN*
M. DERKAOUI*

Much if not most rangeland in Morocco has been overgrazed, particulary where communal grazing is practiced. The damaging effects of overgrazing rangeland are the same throughout the world. In the following review, effects of overgrazing on species compostition, plant growth, water infiltration, and animal performance are discussed, and some pratical recommandations are outlined.

I. EFFECT OF HEAVY USE ON VEGETATION

1. Total non-structural carbohydrate reserves

The reserve material in plants, accumulated in leaf bases, rhizomes and other grass structures (Sullivan and Sprague 1943) consists mainly of carbohydrates (Cook 1966). These carbohydrates are translocated during plant late growth to roots, rhizomes and root crowns where they are stored over winter, and reutilized in spring for new growth (Weinman 1948; Berg 1972). Carbohydrates can also be used for regrowth after harvest (Cook 1966). Consequently carbohydrates are the primary source of energy for the development of range plants (Smith 1972). Although these studies concluded that accumulated carbohydrates are important for regrowth, Richards and Caldwell (1985) found that the number of actively growing meristems were more important for early spring regrowth. Busso *et al.* (1990) reported that carbohydrate reserves were important for regrowth but only when meristematic activity was high.

The effect of grazing or cutting on carbohydrates depends on the kind of plant species subjected to grazing (Robertson 1963) and on the intensity, frequency and season of defoliation (Hedrick 1958). When grasses are actively growing, clipping (Owensby *et al.* 1970) or grazing (El Hassan and Krueger 1980) reduced carbohydrate content of roots and crowns. Severe defoliation induced depletion of carbohydrate reserves, impaired vigor and plant growth, and death of plants (Holscher 1945; Weinman 1948). Drawdown of carbohydrate reserves was greater in big bluestem (*Andropogon gerardii* Vitman) when clipped than when unclipped (Owensby *et al.* 1970). The authors concluded that depletion of carbohydrate reserves increased with delayed time of cutting during the growing season. El Hassan and Krueger (1980) pointed out that

* **Programme Aridoculture/INRA, B.P. 589, Settat**

heavy fall grazing of perennial ryegrass (*Lolium perenne* L.) severely depleted plant carbohydrate reserves. The active growth of ryegrass, when heavily grazed season-long, was delayed about three weeks in spring. Apparently plants used up carbohydrate reserves that could otherwise be used for early spring growth.

Late summer and fall is a critical period for carbohydrate accumulation and root growth of perennial grasses (Weinman 1948). Thus, late-season grazing contributes to depletion of carbohydrates. Carbohydrates are stored when temperature is favorable for photosynthesis and sub-optimal for foliage growth (Youngner 1972). Low temperatures reduce the rate of respiration more than that of photosynthesis in C_3 species, which may enhance carbohydrate storage (Moser 1977).

Intensive clipping is harmful. Both frequent clipping or clipping at less than 10 cm height severely depleted carbohydrates reserves of *Stipa tenacissima* (El Gharbaoui 1978). Everson (1966) clipped western wheatgrass (*Agropyron smithii Rydb.*) at 2.5; 5.0; 7.5 and 10.0 cm height for three months at three-week intervals. He found that carbohydrate reserves were severely reduced as clipping became more intensive. Rhizomes of unclipped plants contained five times more soluble sugars and twice more starch than those of clipped plants. Similar results were reported by Alberta (1957) and Jameson and Huss (1959). Busso *et al.* (1990) reported similar results with non drought stressed plants; but they found little effect from clipping crested [*Agropyron desertorum* Fisch. ex Link (Schult)] or bluebunch wheatgrass [*Agropyron spicatum* (Pursh) scribn. and Smith] on carbohydrates reserves of drought stressed plants. Carbohydrate pools in spring were 7 times higher in drought than non-drought stressed plants regardless of clipping intensity. In general, heavy and frequent top removal gradually decreases carbohydrate reserves in plants.

2. Plant growth and development

Intensive defoliation of plants resulted in reduction and then stoppage of root growth (Robertson 1933 ; Jameson and Huss 1959). Severe removal of photosynthetic tissues impaired root and rhizome growth. Moreover, recovery and growth of above-ground plant parts was slow (Everson 1966), and herbage production declined afterwards (Lodge 1954; Launchbaugh 1957; El Hassan and Krueger 1980). Crider (1955) increased percentage of top removal of several grasses from 0 to 90%. He found that heavy defoliation was detrimental to root growth ; as frequency of clipping increased, roots stopped growing for 25 to 45 days. The author concluded that 40-50% clipping levels were appropriate to balance top removal and root growth. Continued overuse resulted in shallow-rooted plants (Crider 1955; Launchbaugh 1957) with small root biomass (Jameson and Huss 1959; Smoliak *et al.* 1972). Root depth of dominant species in a heavily grazed shortgrass pasture was only 1.4 m; whereas in lightly and moderately grazed pasture, roots penetrated to a depth of over two meters (Launchbaugh 1957). Recurrent clipping reduced number of stems and plant height in shortgrass range (Holsher 1945). Excessive top removal saps the plant below and above ground. Weakened plants are then less able to withstand environmental stresses. Besides decreased plant vigor, overgrazing decreased plant density as well (McConnel and Smith 1970). Heavy use, if continued, would gradually change species composition with disappearance of the most palatable species. As a result, large areas would be left bare to be invaded by less palatable species. Stoddart *et al.* (1975) reported five stages of vegetation regression induced by grazing:

1. Physiological disturbance of climax plants: loss of plant vigor and absence of reproduction of the more palatable species.

2. Composition changes of climax cover. Decrease of palatable species (decreasers), and increase of less palatable and more resistant individuals (increasers).

3. Invasion of new species: annuals may come first, followed by herbaceous or woody perennials of low nutritive value.

4. Disappearence of climax plants.

5. Decreased density of invaders: with continued heavy grazing, invaders may disappear leaving the soil bare and susceptible to erosion.

II. WATER INFILTRATION, RUNOFF, AND SOIL EROSION

Increased number of grazing animals on a particular pasture can reduce plant stand and litter, and increases soil compaction. Consequently, water infiltration would be reduced and runoff intensified. Donahue *et al.* (1977) stated: "when a plant cover, either living or dead (grasses, leaves, mulches), covers the soil surface, the energy of falling water is dissipated by the springy vegetation. As the raindrops fall, the vegetation gives, then the water slides off to be absorbed into the soil". Indeed, water infiltration is directly related to canopy size (Ndawula-Senyimba *et al.* 1971; Brown and Schuster 1969). Launchbaugh (1957) reported that infiltration rate augmented with increased vegetation and dead residue on the soil surface. He found that infiltration rates were 19, 30, and 40 mm ha^{-1}, under heavy, moderate and light grazing, respectively.

Soil compaction under heavy grazing was reported to further decrease water infiltration (Launchbaugh 1957; Rauzi and Hanson 1966; Brown and Schuster 1969). Indeed, heavy grazing significantly decreased pore space in the first 10 cm of soil as compared to light grazing (Rauzi and Hanson 1966). The soil was thus exposed to high runoff and erosion. In South Dakota rangeland, Hanson *et al.* (1970) found that the mean seasonal runoff from May 14 through October 31, over a period of five years, was 20, 15, and 11 mm under heavy, moderate and light grazing, respectively. Weaver (1954) reported that big bluestem and little bluestem {*Schizachyrium scoparium* (Michx) Nash} held the soil five times longer when unclipped than when shoots were removed. Therefore, shoots are as important, if not more, as roots in preventing soil from erosion.

Rice and Pancholy (1973) reported that the amount of ammonium nitrogen was lowest in the first successional stage and highest in climax.

III. ANIMAL PERFORMANCE

Forage quality decreased as the degree of utilization by animals increased (Cook *et al.* 1953). Animals were forced to feed on low quality forage which decreased their productivity. On depleted rangelands, loss of nutrients through erosion deteriorated animal health (Wilson *et al.* 1971). Lodge (1954) reported that heavy grazing decreased protein, calcium and phosphorus contents in plant. In a comparative study on native shortgrass range, Launchbaugh (1957) investigated the effects of grazing intensity on vegetation and beef production. He found that herbage productions were 1228, 1394, and 2200 kg ha^{-1}, under heavy, moderate and light grazing, respectively. The corresponding gains of yearling cattle were 55, 85, and 99 kg per head. In a nutshell, neither plants nor animals do benefit from continued heavy use of plants.

IV. CONCLUSION

In this review, the effects of overgrazing were examined. Direct consequences of heavy use are: reduction in plant carbohydrate reserves, shift in botanical composition toward undesirable species, increased soil erosion, and lowered animal performance.

In planning range use, the first consideration is to ensure that plant and soil ressources are used in such a way that they remain productive under the grazing system used. It has been suggested that proper use would allow 50% of herbage crop ungrazed. Range managers, however, should determine for each individual plant or community of plants, the period of rest required to replenish plant food reserves.

SUMMARY

Heavy grazing on rangeland results in depletion of plant carbohydrate reserves, changes in species composition, reduction in herbage production and decrease in animal performance. Denudation of soil alters the environment by increasing soil temperature, reducing infiltration and accelerating runoff and soil erosion. To prevent these devastating effects, range ecosystem must be managed properly. Range managers should determine for each individual plant, or community of plants, the period of rest required to replenish plant food reserves.

KEY WORDS: Animal performance, carbohydrates, defoliation, overgrazing, rangeland, runoff, soil erosion.

RESUME

Cet article met en évidence les efforts du surpâturage sur les réserves en carbohydrates des plantes, le changement de la composition botanique, la réduction de la production des parcours et la diminution de la productivité des animaux. L'absence de couvert végétal altère l'environnement par l'augmentation de la température du sol, la réduction de l'infiltration de l'eau et l'accélération de l'érosion. Pour pallier à ces efforts négatifs, le parcours doit être exploité rationnellement. Les pastoralistes sont appelés à déterminer pour chaque plante ou communauté de plantes la période de repos pour que les réserves en hydrates de carbones soient reconstituées. Une politique d'encouragement des éleveurs doit être mise en place pour que ceux-ci participent à la conservation des ressources naturelles des terrains de parcours.

MOTS CLES: Performance animale, hydrates de carbones, défoliation, surpâturage, parcours, ruissellement, érosion du sol.

REFERENCES

Alberta, T. (1957). The effect of cutting, light intensity, and temperature on growth and carbohydrate content of perennial ryegrass. *Plant Soil* **8**: 190-230.

Berg, A. R. (1972). Grass reproduction. P. 334-47. In: Youngner, V.B., and McKell, C.N. (Eds.) The biology and utilization of grasses, Academic Press, New York.

Brown, W.B., and Schuster, J.L. (1969). Effects of grazing on a hardland site in the southern high plains. *J. Range Manage.* **22**: 418-23.

Busso, C.A., Richards, J.H., and Chatterton, N.J. (1990). Nonstructural carbohydrate and spring regrowth of two cool-season grasses: Interaction of drought and clipping. *J. Range Manage.* **43**: 336-43.

Cook, C.W. (1966). The role of carbohydrate reserves in managing range plants. Utah Agric. Exp. St. Mimeo Ser. 449.

Cook, C.W., Stoddart, L.A., and Harris, L.E. (1953). Effects of grazing intensity upon the nutritive value of range forage. *J. Range Manage.* **6**: 51-4.

Crider, F.J. (1955). Root growth stoppage -Resulting from defoliation of grass. U.S. Dept. Agric. Tech. Bull. 1102.

Donahue, R.L., Miller, R.W., and Shikluna, J.C. (1977). Soils: An introduction to soils and plant growth. Prentice Hall, Inc., New Jersey, p. 327.

El Gharbaoui, A. (1978). Effet de la période et la hauteur de coupe sur la productivité et les réserves d'hydrates de carbone de l'alfa (*Stipa tenacissima L.*) dans la station de Talsinnt. Mem. 3ème cycle, IAV Hassan II, Rabat.

El Hassan, B., and Krueger, W.C. (1980). Impact of intensity and season of grazing on carbohydrate reserves of perennial ryegrass. *J. Range Manage.* **33**: 200-3.

Everson, A. C. (1966). Effects of frequent clipping at different stubble heights on western wheatgrass. *Agron. J.* **58**: 33-5.

Hanson, C.L., Kuhlman, A.R., Erickson, C.J., and Lewis, J.K. (1970). Grazing effects on runoff and vegetation on western South Dakota Rangeland. *J. Range Manage.* **23**: 418-20.

Hedrik, D.W. (1958). Proper utilization - A problem in evaluating the physiological response of plants to grazing use: A review. *J. Range Manage.* **11**: 34-43.

Holsher, C.E. (1945). The effects of clipping bluestem, wheatgrass and blue grama at different heights and frequencies. *Ecology* **26**: 148-56.

Hulbert, L.C. (1968). Fire and litter effects in undisturbed bluestem prairie in Kansas. *Ecology* **50**: 874-7.

Jameson, D.A., and Huss, D.L. (1959). The effect of clipping leaves and stems on number of tillers, herbage weights, root weights and food reserves of little bluestem. *J. Range Manage.* **12**: 122-6.

Launchbaugh, J.L. (1957). The effect of stocking rate on cattle gains and on native shortgrass vegetation in west-central Kansas. *Kansas Agric. Exp. Bull.* **394**: 2-29.

Lodge, R.W. (1954). Effects of grazing on the soils and forage of mixed prairie in south western Saskatchewan. *J. Range Manage.* **7**: 166-70.

McConnel, B.R., and Smith, J.G.. (1970). Some effects of grazing intensity on bitterbrush dispersion. *J. Range Manage.* **23**: 92-4.

Moser, L.E. (1977). II. Carbohydrate translocation in range plants. In "Rangeland plant physiology". Ed. by Society for Range Management, Colorado.

Ndawula-Senyimba, M.S., Brink, V.C., and McLean, A. (1971). Moisture interception as a factor in the competitive ability of bluebunch wheatgrass. *J. Range Manage.* **24**: 198-203.

Owensby, C.E., Paulsen, G.M., and McKendrick, J.D. (1970). Effect of burning and clipping on big bluestem reserve carbohydrates. *J. Range Manage.* **23**: 358-62.

Rauzi, F., and Hanson, C.L. (1966). Water intake and runoff as affected by intensity of grazing. *J. Range Manage.* **19**: 351-6.

Rice, E.L., and Pancholy, S.K. (1973). Inhibition of nitrification by climax ecosystems. II. Additional evidence and possible role of tanins. *Amer. J. Bot.* **60**: 691-702.

Richards, J.H., and Caldwell, M.M. (1985). Soluble carbohydrates, concurrent photosynthesis and efficiency in regrowth following defoliation; A field study with Agropyron species. *J. Appl. Ecol.* **22**: 907-20.

Robertson, J.H. (1933). The effect of frequent clipping on the development of certain grass seedlings. *Plant Physiol.* **8**: 425-47.

Smith, D. (1972). Carbohydrate reserves of grasses. In V.B. Youngner and C.N. McKell (ed.). The biology and utilization of grasses, Academic Press, New York.

Smoliak, S., Dormaar, J.E., and Johnson, A. (1972). Long term grazing effects on Stipa-Bouteloua prairie soils. *J. Range Manage.* **25**: 246-50.

Stoddart, L.A., Smith, A.D., and Box, T.W. (1975). Range management. McGraw-Hill, Inc. New York.

Sullivan, J.T., and Sprague, V.G. (1943). Composition of the roots and the stubble or perennial ryegrass following partial defoliation. *Plant Physiol.* **18**: 656-70.

Weaver, J.E. (1954). North American Prairie. Johnsen Publishing Co., Lincoln, NE.

Weinman, H. (1948). Underground development and reserves of grasses: a review. *J. Brit. Grassl. Soc.* **3**: 115-40.

Wilson, C.L., Looms, W.E., and Steeves, T.A. (1971). Botany, p. 225. Ed. Holt, Rinehart and Winston, Inc.

Youngner, V.B. (1972). Physiology of defoliation and regrowth. In: Youngner, V.B., and McKell, C.N. (Eds.) The biology and utilization of grasses, Academic Press, New York.