Chapter 7

Using the Nitrogen Balance Approach for Rangelands

The Nitrogen Balance Approach (Chapter 3) includes three variables for calculating a biosolids application rate—the amount of N required by plants and soil (N requirement), the amount of N available from biosolids (net plant-available N, or PAN), and the amount of N available from other sources (N credits):

$$B_{app} = (N_{req} - N_{credits})/PAN \quad (3.1)$$

This chapter presents a method for calculating the net N requirement for rangeland systems ($N_{req} - N_{credits}$). (The method for estimating the PAN from biosolids is given in Chapter 4.).

Unlike agricultural systems, rangelands do not involve the harvest of a specific crop with an expected yield and well-document N requirements. The concept of an "agronomic" application rate loses significance in rangeland situations, especially if single applications are intended to produce multi-year effects. Therefore, other approaches are used to determine biosolids application rates to rangelands. Two such approaches are as follows:

- Use of fertilizer guidelines for rangelands as a substitute for the net N requirement
- Use of biosolids application rates determined from research findings or from careful experimentation coupled with site monitoring

This chapter discusses the possible reasons for applying biosolids to rangelands and then discusses these two approaches for determining appropriate application rates for particular sites.

Application of biosolids to rangelands

Application of biosolids to rangelands is of great interest because of the vast area of range that occupies western North America. Rangelands offer a potential place for management of a large amount of biosolids. In many cases, suitable range sites are more accessible than agricultural areas yet are more isolated from houses and other sensitive land uses. More importantly, biosolids can improve the productivity and ecology of rangelands.

Rangeland is a type of natural land area that supports vegetation but is neither forested (in large proportion) nor cultivated for crop production. It is commonly managed for grazing livestock, principally cattle and sheep, but it also provides habitat and forage for wildlife and outdoor recreation for people. Rangelands are typified by the open arid expanse of grassy and shrub-covered terrain seen in cowboy movies. Most of the rangeland in western North America is public land, and much of it fits the Hollywood image. The rangeland that is privately owned still represents a large amount of land. They are often fenced and intensively managed for grazing.

In contrast to agriculture, rangeland is characterized by a mixed assortment of mostly perennial plants, by reliance on seasonal natural precipitation, and by no harvest, tillage, or cultivation. Range conditions tend to be harsh. The climate of rangelands in the inland Northwest is predominantly arid or semiarid with cold winters and hot summers. Precipitation is seasonal and inconsistent from year to year. Lack of water usually limits plant growth. Vegetative growth fluctuates through the year and from year to year, depending on temperatures and the amount of moisture available from precipitation. When water is abundant, availability of nutrients, particularly N and P, determine plant growth. Well-adapted native vegetation (grasses, forbs, and shrubs) survives these conditions and supplies forage for livestock and wildlife. However, rangeland ecology is fragile and environmental changes can alter its character and quality. During the late nineteenth and early twentieth centuries, unrestricted grazing degraded much of the range in the western United States. The resulting effects—reduced forage value, undesired plant species, and erosion—still persist in many areas today.

Although it is not a common practice, fertilization has long been recognized as a way to enhance the quantity and quality of range forage. Organic sources of nutrients, such as biosolids, provide fertility for several years through the gradual release of nutrients as organic matter decomposes. In addition, biosolids serve as a soil amendment, improving the soil and water conditions. To minimize disturbance to the soil and plants, biosolids are surface applied to range soils without incorporation.

Benefits of biosolids application

Research studies have shown that surface applications of biosolids to arid and semiarid rangelands can yield the following benefits:

- Increase water infiltration and soil moisture retention, thereby decreasing runoff and erosion (Loftin and Aguilar, 1995; McMurry, 1995; Moffet et al., 1995)
- Increase vegetative growth and cover (Loftin et al., 1995; Wester et al., 1995)
- Reduce wind erosion (Harris, 1995)
- Improve forage quality and palatability with higher concentrations of nutrients in plant tissues (Loftin et al., 1995; Fresquez et al., 1990b)
- Promote specific desired plant species (Redente et al., 1995; Benton and Wester, 1998) or inhibit unwanted species (Fresquez et al., 1990a)
- Lower concentrations of potentially toxic elements (such as Mo and Se) in plant tissues (Pierce et. al., 1995)
- Help restore degraded rangelands (Loftin et al., 1995; Fresquez et. al., 1990a)

The application of biosolids to rangelands also has possible drawbacks, such as accumulation of salts in soils and plants, undesired changes in plant species composition, movement of nitrate and other compounds with soil water, and overgrazing of areas fertilized with biosolids. However, research indicates that these drawbacks present little risk or can be avoided with appropriate management. On balance, therefore, application of biosolids to rangelands is a beneficial and safe practice.

Recommended application practices

The fertilization and soil-amending properties of biosolids will last for several years. Research suggests that the effects of biosolids continue for 5 years or more after an application to rangeland. Given the long-term benefits and the variable growth of range vegetation, it may be more practical to make one biosolids application every several years, rather than apply biosolids annually.

If possible, applications should be made in the fall or winter. Studies conducted in western Texas found that plants responded better to biosolids applied in the dormant season compared to applications made just prior to and during the growing season (Wester et. al., 1995). With spring applications, biosolids may act as a mulch and interfere with water movement into the soil after light rains. Leaching of nitrate from biosolids over the winter and early spring is less of a concern in range environments because of the limited amount and movement of water in the soil.

Because range plant species respond differently to biosolids-altered conditions, applications can affect the botanical composition of the site. Generally, biosolids application favors grasses and forbs (non-grass herbaceous plants) over legumes. Shrub response is species-specific. In addition, research has shown that biosolids applications can encourage growth of certain desired plants, depending on the nature and status of the site. Given that biosolids can alter the composition of the plant species, a range specialist should be consulted in evaluation of the biosolids application site, rate, and procedures.

Determining biosolids application rates

The following sections describe two approaches to determining biosolids application rates for rangelands:

- Use of fertilizer guidelines for rangelands as a substitute for the net N requirement
- Use of biosolids application rates determined from research findings or from careful experimentation coupled with site monitoring

Using fertilizer guidelines for local rangelands

If available, recommended application rates for fertilizing rangelands can provide the basis for calculating a "surrogate" biosolids application rate. The fertilizer recommendation represents the net N requirement (N_{req} - $N_{credits}$) for the rangeland plants. The biosolids application rate (B_{app}) can be determined by dividing the N requirement (fertilizer recommendation) by the amount of plant-available N (PAN) from the biosolids for the first year of the application (Chapters 4 and 5).

$$B_{app} = \text{(fertilizer recommendation)/PAN}$$

The N fertilization recommendation used should be specific to local range conditions. Nutrient requirements depend to a great extent on climate and plant species. As a result, suggested range fertilizer rates found in publications vary greatly, from roughly 20 to 200 lb/ac. If local range fertilizer guidelines are not available, a range specialist should be consulted or a safe target application rate should be used (as described in the following section).

Once a guideline is selected, it is important to take into account the distinctions between this procedure and the Nitrogen Balance Approach (Chapter 3). One distinction is that a fertilizer recommendation is not strictly equivalent to the N requirements of the plants. It is an umbrella value determined from research data or judged from previous experience. It assumes that the site does not have a large reserve of available soil N, which is usually the case for rangelands. Therefore, no subtraction of N credits is included in the calculation. If biosolids or manure may have been applied to the site in the recent past, a soil sample should be collected and analyzed and/or the amount of N provided by previous applications of biosolids or manure should be estimated (Chapter 4).

In addition, the calculation of PAN in the biosolids must take into account that range conditions are not conducive to N losses through denitrification but are very conducive to N losses through ammonia volatilization. Volatilization losses can be relatively large because of the hot, dry conditions and because biosolids are surface applied without soil incorporation. The conventional assumption is that 50 percent of the ammonia present is volatilized if the biosolids are applied during the cool, wet season and that 100 percent is volatilized if biosolids are applied in the hot, dry season.

Using target application rates

If fertilizer guidelines are not available, a safe “target” biosolids application rate can be assumed, followed by site monitoring to assess the effects of the application. Depending on range management goals (increased forage quality or range restoration), the site can be monitored for a number of variables, including forage production, changes in plant species composition, amount of soil organic matter, concentrations of nitrate and metals at various soil depths, volume and quality of runoff, and chemical composition of plant tissues. The rate for subsequent applications can be adjusted up or down according to site monitoring results.

Research findings can form the basis for selecting a target biosolids application rate that improves range productivity and conditions as much as possible without potentially causing environmental damage. Several research studies have applied biosolids to rangelands at various rates and then monitored the effects on forage production and environmental conditions. Application rates of up to 40 dt/ac have been investigated. The studies have shown that benefits result even from low application rates, as low as 2 dt/ac. Generally, plant growth and nutrient concentrations increase as application rate increases. However, in some studies, growth was reduced at application rates approaching 40 dt/ac. Potential environmental impacts also tend to increase as application rate increases, although runoff volume may actually decrease as the rate increases. In interpreting research findings, differences in the nature of the biosolids, climate, and range ecology should be taken into account.

Selected examples of research findings are as follows:

- Based on research in degraded rangeland in north central New Mexico, Loftin et. al. (1995) recommend an application rate of 20 dt/ac, which appears to keep trace metal concentrations in the soil and plants at safe levels.
- In a Texas desert grassland, Wester et. al. (1995) found that production of selected grasses generally improves at biosolids application rates up to 8 dt/ac and, in most cases, higher rates lead to further improvements.
- Studying biosolids application in a semiarid sagebrush ecosystem in Colorado, Pierce et al. (1995) found that an application rate of 5 dt/ac effectively supplies essential plant nutrients. They suggest that application rates greater than 9 dt/ac may pose the potential for movement of nitrate to surface water in the first year following application.

Experience of non-researchers can also help in choosing a target application rate. On ranches that apply biosolids to rangelands, application rates of 2 to 5 dt/ac are common (Gallier et al., 1993). These are lower than the rates that research has generally found to be effective and environmentally safe. Because low application rates appear to be beneficial and because range acreage is abundant, it seems prudent and reasonable to initially set a low target application rate (about 2 to 5 dt/ac).

Recommended management practices

Again, because the status and ecology of the site can be altered, it is very important that a range specialist be involved with the planning, management, and evaluation of the application. The application of biosolids should complement the management goals for the range, rather than using the range simply as an outlet for biosolids. Rangeland sites that are already in peak condition or that include critical wildlife and plant habitats may not be good candidates for biosolids applications. As with any biosolids application, conditions that may lead to contamination of groundwater and surface water should be avoided. This includes application of biosolids to steep slopes, riparian areas, wetlands, and snow covered ground near surface water.

Grazing restrictions must be observed if biosolids do not meet pathogen and vector reduction criteria. In the United States, a 30-day waiting period for grazing is required for Class B biosolids. In general, grazing should be monitored on range fertilized with biosolids. It is possible that animals will overgraze fertilized areas because of the improved forage quality and palatability.

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