LAND APPLIED BIOSOLIDS RESTORE DISTURBED RANGELANDS

MANY RANGELANDS in the western U.S. have experienced heavy livestock grazing that has led to substantial reductions in forage quality and quantity. Other environmental and ecological consequences associated with overgrazing on western rangelands include: 1) Reduction in moisture infiltration and retention; 2) Decreases in vegetative diversity and forage yield; and 3) Increased loss of topsoil.

Negative impacts from overgrazing are interrelated and addressing them requires a systematic and sustainable approach. For example, any rangeland restoration approach that has the net value of increasing forage cover will not only improve the land's grazing value but will also enhance moisture infiltration and reduce soil erosion.

Treated municipal sewage sludge or biosolids is a valuable and inexhaustible resource for restoring the vigor of disturbed rangelands. Biosolids represent a low cost source of organic matter as well as provide buffering capacity when land applied. Organic matter decomposition from land-applied biosolids releases chemically bound nutrients (nitrogen and phosphorus), making them available for assimilation by plants and soil microorganisms.

Biosolids land application on arid or semiarid rangelands poses little threat to groundwater resources in areas with adequate groundwater depths because evapotranspiration generally exceeds total precipitation. Climatic variables including temperature, rainfall intensity and frequency are important in determining both the rate of rangeland recovery following biosolids land application as well as the types of vegetative species that will become established.

This current study was focused on evaluating the potential of land applying aerobically digested, anaerobically digested and lime-stabilized biosolids to improve the forage and soil quality at disturbed western U.S. rangelands.

Initiation of beef production starts with preparation of livestock for eventual grazing on rangeland. Preranging activities include the branding (above) and castration of bull calves as well as the branding of heifers.

To counter impacts of heavy grazing, organic matter decomposition from biosolids releases nutrients — making them available for plants and soil microorganisms.

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METHODS USED ON TEST PLOTS

Biosolids were surface applied at various rates on one-third acre test plots separated by buffer strips on private rangeland located in Tooele County, Utah. The agronomic rate (tons/acre) for the surface application of biosolids was determined based on the assumption that a healthy rangeland would exhibit an adjusted nitrogen requirement of 150 lbs of nitrogen per acre. This nitrogen demand was based on the assumption that a healthy rangeland would be dominated by perennial grass species. Biosolids were land applied on rangeland test plots at ten times (10x), five times (5x) and one time (1x) the estimated agronomic rate.

Each of the one-third acre test plots was divided into 144 sections (i.e., subplots) having physical dimensions of 10 feet by 10 feet (i.e., 100 ft^2). During field sampling, six 10 feet by 10 feet subplots from each one-third acre test plot was sampled for forage and soil properties. The mean value for each parameter of interest was estimated using data from all subplots of a particular treatment. To minimize operational costs, after biosolids were surface applied on the rangeland plots, the plots were managed without any supplemental tilling, irrigation or reseeding during the course of the field study.

To estimate the effect of land application of biosolids on vegetative growth, forage from each of the six test plot sections as well as the control test plot were sampled. Forage yields were determined by collecting forage using a standard gas powered lawn mower. The entire 100 ft^2 test plot sections were mowed during forage sampling. The harvested material was collected in plastic bags and weighed on site to obtain an estimate of the forage yield. For every test plot, results from statistically analyzing the six mowed 100 ft^2 sections was used to generate a mean wet-weight forage yield (lbs/acre). To convert wet weight to dry weight, forage samples from each treatment (including the control) were selected at random and dried at 103ºC for two hours to establish a dry weight value. The estimated ratio of dry weight to wet weight was used to convert all wet weight values into dry-matter forage yield values.

ESTIMATING FORAGE NUTRITIONAL VALUE

In evaluating the impact of biosolids land application on forage nutritional value, three parameters are of particular importance: crude protein, relative feed value and specific animal stocking rate. Crude protein is a measure of the amount of nitrogen in a forage crop. Crude protein is estimated by multiplying the total nitrogen content by a constant, 6.25. The value of the constant is based upon the assumption that forage protein contains approximately 16 percent nitrogen (by weight).

Relative feed value (RFV) is an index used to compare forage quality to the feed value of alfalfa. RFV is used to determine how well forage will be consumed and digested. Two important parameters whose value impacts the RFV level are the forage's acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents. ADF reflects the content of cellulose and lignin in forage and is closely related to digestibility.

In general, a higher RFV reflects a greater digestibility of forage. A RFV value of between 110 and 125 reflects an adequate forage value for grazing cattle. However, for lactating animals, an RFV of at least 140 is desirable.

Stocking rate is the number of animals that a parcel of land (pasture, rangeland, etc.) can nutritionally support during a grazing season. It is normally assumed that one animal unit (1,000 lb beef cow) has a daily feed requirement of 26 pounds of dry matter forage. Therefore, over a four month grazing season (120 days), one animal unit requires approximately 3,120 lbs of dry matter forage. From this forage matter requirement, the stocking rate can be estimated.

BACKGROUND SOILS

Deep soil sampling consisted of taking soil samples at 0.75, 2, 3, 4 and 5 foot depths below the ground surface (bgs) in each of the six test plot sections. Parameters that were analyzed for each soil sample included the following: 1) nitrate; 2) ammonia; 3) available phosphorus; 4) electrical conductivity (EC); 5) sodium adsorption ratio (SAR); and 6) pH. Evaluation of the background soils data indicated that the nitrate concentrations were significant throughout the soil profile. This observation reflects a high level of historical animal grazing (nitrate source) in combination with a relatively limited amount of vegetative cover.

In addition to the high nitrate concentrations, soils analyses indicated that the biosolids land application site had an average EC and SAR significantly above 4.0 and 13, respectively. These findings confirmed that the biosolids land application site was both saline (high salt concentrations) and sodic (high sodium content). Using the average nitrate and ammonia concentrations found in the surface soil (i.e., 0.75 foot depth), the plant available nitrogen (PAN) per acre of soil was estimated to be 98.6 lbs nitrogen/acre.

Table 1 provides a summary of the average concentration of nitrogen species found in the aerobically digested, anaerobically digested and lime-stabilized biosolids used in

Lime stabilized (left) and aerobically digested biosolids (right) are stockpiled on disturbed rangeland prior to their surface application.

Reprinted From:
September, 2007
BIOCYCLE
ADVANCING COMPOSTING, ORGANICS RECYCLING & RENEWABLE ENERGY
419 State Avenue, Emmaus, PA 18049-3097
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the field study. Using the average nitrate and ammonia concentrations found in the surface soil (i.e., 0.75 foot depth), the plant available nitrogen (PAN) per acre of soil was estimated to be 98.6 lbs nitrogen/acre.

Given an assumed rangeland nitrogen requirement of 150 lbs/acre, the nitrogen-based agronomic rates for the aerobically digested, anaerobically digested and lime stabilized biosolids were estimated to be 1.5, 0.8 and 8.8 tons/acre, respectively. Following 18-months after biosolids land application, all of the biosolids test plots were sampled for forage dry-matter yield, forage nutritional levels as well as specific soil chemical parameters at depths ranging up to 5 feet below the ground surface.

FORAGE SAMPLING

Biosolids land application was observed to increase forage production above that which was recorded for the control plots in all cases. Although lime stabilized biosolids applied at one times the agronomic rate were found to generate forage yields comparable to the levels recorded for test plots amended with either aerobically digested or anaerobically digested biosolids, when lime stabilized biosolids were added at higher multiples of the agronomic rate, the forage yield decreased significantly. Table 2 includes data on the application rates and forage yields.

The scientific explanation for the inverse relationship observed between forage dry matter yield and biosolids application rate for lime stabilized biosolids is unclear. Several possible explanations included the following: 1) Increased application of calcium-based salts was toxic to rangeland vegetation; 2) Large amount of biosolids applied to achieve the desired application rate physically obscured sunlight thereby reducing the emergence of rangeland forage; and 3) High pH of lime stabilized biosolids reduced the availability of plant micronutrients (e.g., metals).

Finally, ecological analysis indicated that the dominant plant species found on the control test plots was *Bromus tectorum* (cheat grass) while the dominant vegetative species found on the test plots amended with biosolids was *Hordeum marinum gussoneanum* (seaside barley). Other minor plant species found on sites receiving biosolids included *Descurania brassicaceae, Halogeton glomeratus* (saltlover) and *Kochia scoparia* (summer cypress).

Crude protein content in forage from biosolids amended rangeland varied from 15 to 20 percent, whereas the untreated control plot was about 10 percent.

SOIL SAMPLING

With respect to rangeland test plots receiving aerobically digested biosolids, nitrate concentrations were observed to increase with increasing depth for all treatments. Plant available phosphorus concentrations were found to have their largest values at the soil surface and decreased significantly with soil depth. These observations were not surprising since nitrate is relatively mobile and is easily transported through the soil matrix. On the other hand, phosphorus can readily interact with surface soil constituents (e.g., metals) and remain relatively immobile. The behavior of the electrical conductivity was similar to that of nitrate while soil ammonia concentrations remained relatively low for all application rates.


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2

Disturbed western rangelands are characterized by limited amounts of native grasses, high concentrations of invasive weeds and large areas of topsoil erosion (1). Biosolids are land applied using a manure-type spreader (2). View of vegetation established on disturbed rangeland by applying biosolids at five times the agronomic rate (3).

The behavior of the soil chemical parameters for those plots receiving anaerobically digested biosolids was similar to that observed at those rangeland plots that had received aerobically digested biosolids. The one notable exception was the behavior of nitrate particularly at the higher biosolids loading rates. The rangeland plots that had received anaerobically digested biosolids were found to have significantly less nitrate in the soil than the rangeland plots that had received aerobically digested biosolids.

There are several possible reasons for this observation including: 1) A greater fraction of the nitrogen added in the anaerobically digested biosolids was lost from the test plot through ammonia volatilization; 2) Denitrification losses of nitrate were larger in rangeland test plots receiving anaerobically digested biosolids; 3) Nitrate leaching losses may have been accelerated within the rangeland test plots that received anaerobically digested biosolids; or 4) Organic nitrogen mineralization rate may have limited the production of nitrate in rangeland test plots amended with anaerobically digested biosolids.

The behavior of the soil chemical parameters at rangeland test plots that received lime-stabilized biosolids was similar to that behavior found at those sites that had received aerobically digested and anaerobically digested biosolids. As expected, nitrate concentrations increased both with depth as well as with increasing biosolids land application rate.

ENHANCED FORAGE QUALITY

The impact of biosolids land application on forage quality is summarized in Table 2. Results confirmed that, while the average dry matter forage yield of control plots was 84.1 lbs per acre, the dry matter forage yield for aerobically digested, anaerobically digested and lime-stabilized biosolids ranged from 131.0 to 664.1 lbs per acre. Although the increase was not surprising given the fertilizer and soil conditioning value of biosolids, the significant increase in vegetative quality was both surprising and compelling. Forage from the control plots was found to have a crude protein content of approximately 10.15 percent, which was lower than the crude protein content found in the forage collected from all biosolids amended rangeland plots. Forage grown on biosolids-amended rangelands reported maximum crude protein contents of 19.67 percent, 15.26 percent and 20.22 percent for aerobically digested, anaerobically digested and lime-stabilized biosolids land application sites, respectively.

Beyond the difference in crude protein content, RFV for forage grown on rangeland test plots amended with land applied biosolids was substantially greater than the RFV of forage grown on the control plots. These results suggest that the forage grown on rangeland plots amended with land applied biosolids were both more nutritious (higher protein) and more digestible than the forage grown on the control plots.

The environmental and economic implica-

Table 1. Average concentration of nitrogen species in biosolids

Biosolids Type	*Total N (%)*	*Nitrate (mg/kg)*	*Ammonia (mg/kg)*
Aerobically digested biosolids	5.41	1.71	2135
Anaerobically digested biosolids	5.85	13.4	12,500
Lime stabilized biosolids	0.89	1.22	1175

Table 2. Results from forage value analyses

Biosolids Type	Application Rate	Forage Dry (lbs/acre)	Dry Mass Basis (%)	Relative Feed Value	Animal Stocking Rate*
Control	not applicable	84.10	10.15	93.53	75.49
Aerobically digested	1X	423.40	19.40	114.04	15.34
Aerobically digested	5X	354.20	19.67	117.91	18.94
Aerobically digested	10X	489.50	15.85	100.32	13.15
Anaerobically digested	1X	612.25	15.26	112.58	10.68
Anaerobically digested	5X	559.84	13.62	108.85	11.58
Anaerobically digested	10X	376.03	14.33	109.62	17.33
Lime stabilized	1X	395.64	14.30	112.36	16.72
Lime stabilized	5X	180.79	16.57	105.57	36.09
Lime stabilized	10X	131.01	20.22	109.23	50.60

**Assumes that one beef cow weighing 1,000 lbs is grazing on the rangeland for 120 days.*

tions of enhanced forage quality and quantity as a result of biosolids land application are significant particularly in light of its impact on sustainable ranching activities. For example, in examining the animal stocking rate, to support one grazing animal (e.g., 1,000 lb beef cow) for 120 days on rangeland having the same nutritional quality and dry matter yield as the control plot would require at least 75.5 acres of land. In comparison, for rangelands that have been amended with aerobically digested, anaerobically digested and lime-stabilized biosolids, the increase in forage nutritional value and quantity could potentially reduce the land needed to support the same animal over the 120-day grazing period to 9.7 acres, 10.7 acres and 16.7 acres, respectively. Increasing the number of grazing animals that can be supported on the same amount of land can significantly reduce the scope of any environmental impact while increasing the financial revenues for ranching activities.

PROJECT OBSERVATIONS

Land application of biosolids was found to be a technically effective and environmentally sound approach for restoring disturbed western U.S. rangelands. Without supplemental irrigation, tilling or seeding, land application of aerobically digested, anaerobically digested and lime-stabilized biosolids at rates much greater than the agronomic rate were demonstrated to lead to significant increases in forage yield when compared to control plots. While the control plots had an average forage yield of 84.1 lbs/acre (dry weight), a maximum forage yield of 664.1 lbs/acre (dry weight) was recorded on rangeland test plots that had received land applied biosolids. Forage yields were found to increase with increasing biosolids application, a fact that seemed to suggest that the disturbed rangeland soils were nutrient limited.

Nitrate concentrations were found to be high in all plots including the control. The reason for the high nitrate concentrations in the control was unclear but suspicion falls on the historical use of the site as an animal holding and feeding area. Moreover, the effect of large biosolids land application rates on soil nitrate concentrations was not surprising. As biosolids loading rates increased, the amount of nitrate detected in the soil increased. Any nitrate not utilized by rangeland forage was expected to leach below the root zone. In spite of the increase in nitrate concentrations, a large depth to groundwater (>80 feet in this case) and/or naturally poor groundwater quality are important site characteristics that can ameliorate any environmental and/or public health concern associated with nitrate leaching.

In all rangeland test plots, the largest plant available phosphorus concentrations were found associated with the surface soil layer (i.e. top 0.75 foot depth). This observation was not surprising since phosphorus tends to rapidly react with soil metals (e.g., calcium, iron, etc.) forming relatively insoluble complexes. Accumulation of phosphorus in the surface soils has significant environmental implications. Effective phosphorus management from rangelands amended with biosolids will require implementation of procedures that minimize soil erosion (e.g., over land moisture flow) as this is the primary mechanisms by which phosphorus can become mobilized and potentially impact surface water quality.

Like nitrate, salt concentrations were found to increase with increasing depth. Since the salt concentrations are dependent on moisture movement including unsaturated moisture flow, the level of precipitation relative to evapotranspiration will determine the rate, extent and direction of salt movement within rangeland soils.

Finally, the enhancement of forage quantity and quality on rangelands amended with biosolids underscore the value of biosolids in supporting sustainable ranching practices. Land applied biosolids represent a valuable and inexhaustible resource that can be utilized to restore the vegetative vigor of disturbed and/or marginal rangelands. Results from the current study demonstrate that land application of biosolids not only increases the forage and, therefore, the economic value of rangelands to ranching interests but collection of land leasing and biosolids tipping fees from municipal wastewater treatment plants can be a significant source of financial revenue for ranchers who agree to utilize biosolids on their property. ■

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The authors would like to thank the following individuals for their support in planning and implementing the biosolids field demonstration program: Randy Cassidy and Todd Thackery (Ensign Ranches, Inc., Skull Valley, Utah), Mike Scharp (Parker Ag Services, Colorado Springs, Colorado), Dan Olson (Tooele City Wastewater Treatment Plant, Tooele, Utah) and Reed Fisher (Central Valley Wastewater Treatment Plant, Salt Lake City, Utah). The authors would also like to acknowledge the graduate student financial support received by EPA Region 8 (Denver, Colorado), State of Utah Division of Water Quality and the Utah Water Research Laboratory (Utah State University, Logan, Utah).