Effects of Natural Gas Well Development and Reclamation Activities on Topsoil Properties

Proposal Submitted to the University of Wyoming School of Energy Resources
2007-08 Matching Grant Fund
April 15, 2008

Summary: Maintaining and restoring productivity of topsoil disturbed by energy development is crucial to successful reclamation. In this interdisciplinary project, we propose 1) to evaluate condition of topsoil before, during, and after reclamation in three Wyoming ecological sites to better understand how development/reclamation processes degrade soils, and 2) to evaluate a novel approach to speed recovery of soil processes on reclaimed sites using controlled livestock impact. The project fosters education of graduate and undergraduate students and extension to the restoration/reclamation community.

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PROJECT DESCRIPTION

Soils are complex, intertwined systems that determine the ecological productivity, resistance, and resilience of ecosystems. Soil systems develop over millennia of interaction with physical and biological environments to form soil horizons where the surface, or A horizon, is the most intensively altered by the environment through weathering, leaching, and inputs of organic materials. A horizons (topsoil or surface soil) support the bulk of biological activity in soils, including cycling of nutrients that support plant growth, and can be thought of as highly structured networks of plant roots, fungal hyphae, soil organisms, and decomposing organic materials. Well-developed A horizons facilitate infiltration of water and air that supports biological activity, but also slow decomposition and conserve organic materials by protecting them in stable soil structural units (peds). Subsoils, or B horizons, are typically zones of accumulation where clays, calcium carbonate, salts, and other materials that can be transported by water are deposited. Subsoils are important reservoirs for soil water but are much lower in nutrients and higher in clays and salts than A horizons. In dry environments, A horizons are typically very thin with relatively little soil organic matter (SOM). Subsoils can be especially high in calcium carbonate, salts, and sodium.

Topsoil Issues: Thin, nutrient poor topsoil, combined with subsoil potentially high in salts, reduces the resilience of arid and semiarid soil systems following drastic disturbances. Scraping and stockpiling topsoil, as is typically done during energy development activities, drastically disrupts the soil system and stimulates decomposition and loss of SOM by breaking apart soil structure that protects SOM. Organic matter is usually further diluted by mixing with the upper part of the subsoil because it can be very difficult to scrape only the A horizon in thin dryland soils. Mixing of clays, salts, and sodium into topsoil further reduces its ability to recover once a site is reclaimed.

Controlled Livestock Impact: Though both Wyoming ranchers and surface mining companies use livestock grazing to control weeds as part of restoration after a new plant community is developed, this experiment would not use grazing. Instead, cattle confined on reclaimed and dormant-seeded well pads would be fed hay for a short period (<7 days) to add, process, and incorporate organic materials. Livestock managers support this approach but it has not been scientifically evaluated. According to articles published on the website http://www.ecoresults.org, livestock managers in Arizona and Nevada restore native grasses on abandoned mine tailings using short periods of confined feeding at high stocking rates on seeded areas. Articles on the website http://managingwholes.com/--environmental-restoration.htm claim that high livestock impact for short duration breaks soil crusts, improves seed-soil contact, mulches and fertilizes the soil, and helps control weeds. A recent article in the Canadian Farm Manager Newsletter (http://www.farmcentre.com/News/CFMNewsletter/Archives), called Letting Cows Do the Work, describes winter feeding on dryland pastures to improve soils and increase production.

Although these articles offer no scientific evaluation, there is logic to the notion that cattle could process and incorporate organic materials into degraded topsoils more cheaply than other methods. Livestock managers with life-long experience in southern Wyoming use these techniques and are convinced that this would be an economical approach toward restoring soil biological components inevitably lost during energy development. The Wyoming Game and Fish Department (WGFD) cooperates with ranchers to successfully restore native forage on wildlife management areas using this technique. Observations by WGFD indicate improved soil conditions and greater success in restoration seedings (personal communication, Ryan Amundsen, WFGD). We believe that tightly controlled livestock impact as a reclamation tool warrants scientific evaluation for Wyoming natural gas well pads. This approach could support local economies and improve relations between livestock permittees, energy companies, and leasing agencies by giving local livestock producers a stake in successful reclamation.

Approach and Need for Information: In this collaborative project among the Renewable Resources Department, Cooperative Extension, the Wyoming Restoration and Reclamation Center, and the Agriculture and Applied Economics Department, we propose to monitor key components that control ecological resiliency and productivity in topsoils before, during, and for three years after reclamation of natural gas well pads in three key ecological sites in southern and southwestern Wyoming. On part of each selected well pad, we propose to cooperate with local livestock permittees to evaluate the efficacy of controlled livestock impact for facilitating reclamation. The project would support graduate and undergraduate education as well as extension of important information to reclamation practitioners.

Information that would be provided by this study is badly needed by energy companies and land management agencies responsible for reclamation of gas well pads and related activities. As natural gas development continues in difficult-to-restore environments, mounting cumulative impacts could detrimentally effect ecological values and functions, such as wildlife habitat and water quality. Improved understanding of how important soil processes recover following reclamation, and whether a novel approach utilizing livestock impacts speeds recovery, will enable improved reclamation activities. We believe that this survey-level study will improve reclamation success and will lead to more refined research questions for investigating improved, ecological-site-specific reclamation techniques.

Objectives: 1) Determine topsoil impacts of development and reclamation practices across important ecological sites; 2) Evaluate efficacy of controlled disturbance by cattle for facilitating recovery of soil processes in well-pad reclamation; 3) Extend information to professional, agricultural, and scientific communities through appropriate publications, presentations, and training sessions.

Research Objectives and Approaches: **Objectives 1 & 2:** We will use GIS layers showing well-pad locations to be developed in 2008 or 2009 (start date depends on funding availability), vegetation, soils, and ecological sites, to randomly select three planned well pads (replications) from each of three key, widespread ecological sites (e.g., loamy 10-14” precip., shallow loamy 7-9” precip., and saline upland 7-9” precip., for instance) for a total of nine sites. Each planned well pad area will be divided into three treatments: 1) no livestock impact; 2) optimal livestock impact; and 3) adjacent undisturbed area. After reclamation, each well pad will be divided in two with solar powered electric fences. We will cooperate with area livestock permittees to arrange for transporting and feeding cattle on each site (see attached letter). Since the livestock impact will occur in late fall after dormancy, timing will not be crucial and we will be able to move the same group of cattle and associated equipment from replication to replication within a region. The optimal intensity (head/area and number of days) will be determined by consensus among the ranchers involved in the project and will be held constant at each study site.

- **Field sampling procedures:**
  - Baseline and post-reclamation soil and vegetation monitoring: To monitor effects of well pad development and reclamation (Objective 1) and effects of livestock treatments (Objective 2) on soil processes, three transects will be established in each of the three treatments at each of the nine sites. Three monitoring plots will be established along each transect and recorded by precision GPS. Vegetation cover by species will be recorded in 1-m^2 plots at each point, including assessment of germination and establishment on reclaimed sites. Soil samples collected along each of the transects from the A and B horizons at each plot will be bulked by depth for each treatment (18 total samples per site per sampling). These data will be collected shortly before disturbance, immediately after reclamation, and then seasonally (spring, summer, fall) during years 2 and 3 (18 samples x 3 ecological sites x 3 replications = 162 samples each seasonal collection x 8 sampling times over 3 years = 1296 total samples).
  - Soil morphology: To monitor soil development on reclaimed sites (Objective 1), soils will be described and sampled by horizon to 1.5-m depth prior to disturbance near the center of the no livestock treatment. description and sampling will be repeated to at least 50 cm immediately after

reclamation and then at the end of year 3 (~5 soil horizons per site x 9 sites = 45 samples x 3 samplings = 135 total samples);
    - Topsoil monitoring: To determine impacts of scraping and stockpiling on topsoil characteristics (Objective 1), soil cores collected from 0- to 5-cm, 5- to 20-cm, and 50-cm depth increments below 20 cm from the surface to the bottom of the pile at three locations on each stockpile will be bulked for each depth increment. These samples will be collected just after stockpiling and again just before reclamation (9 sites x ~6 depths x 2 times = approximately 108 samples).
- **Laboratory analyses:** To assess soil processes within the three treatments and stockpiled topsoils we will quantify chemical, physical, and biological parameters in each soil sample. Relatively stabile soil properties, such as pH, EC, texture, available phosphorus, and total organic carbon (C) and nitrogen (N), will be measured one time from each sample set (~360 one-time analyses). Soil properties known to respond rapidly to disturbance and management activities, such as labile soil organic matter components important to microbially mediated nutrient cycles (i.e., mineral and mineralizable C and N, dissolved organic C and N, microbial biomass C and N), will be measured seasonally in each sample set (1539 total samples over three years);
- **Economic analysis:** Working with Dr. Matt Andersen, UW Dept. of Ag & Applied Economics, we will carefully record costs associated with the livestock treatment to determine the feasibility of this approach based on any ecological benefits we measure. We can then compare those costs with other ways of achieving similar benefits. We will also determine the value of less tangible potential benefits, such as involving local agricultural communities in the natural gas development process and keeping development dollars in local communities.

Objective 3: In a collaborative effort with the UW Cooperative Extension Reclamation Education Issue Team, reclamation bulletins will be developed from objectives 1 and 2 and results will be presented by Extension Educators and Specialists at restoration and reclamation meetings. Also, results will be presented at other scientific meetings and reported in peer-reviewed venues.