The use of composted municipal waste to revegetate a high elevation mine site
by Gary Lynn Vodehnal

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Land Rehabilitation
Montana State University

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Mining in alpine and subalpine areas frequently results in surface soil coverings of spoil and overburden that differ substantially from pre-mining soils. These severely disturbed sites frequently require amendments to accelerate the development of desirable nutrient cycles and provide a hospitable growing medium for plants. Composted municipal wastes are becoming more available as greater emphasis is placed on waste reduction at the community level. A market for these waste-generated compost products may be found in the reclamation of disturbed areas. This project evaluated the effects of two types of composted municipal waste and a commercial nitrogen fertilizer on plant establishment, cover, and production. The study site is located at a heap leach gold mine at an elevation of 2,300 meters, 25 kilometers southwest of Helena, Montana. Thirty three plots were established to measure seedling density, vegetative cover, and plant production over two growing seasons. Plots treated with the higher, incorporated rates of EKO sludge compost and Bozeman municipal yard waste compost produced significantly greater plant density, cover, and biomass than the commercial nitrogen fertilizer and unamended top soil treatment. Compost incorporated into the surface horizon produced greater plant cover and biomass than surface applications. After two growing seasons total grass cover and production were significantly greater than all other treatments with the higher rate of incorporated EKO compost. Forb cover and production were significantly greater than all other treatments with the higher rate of incorporated Bozeman compost. Results from this field study suggest that composted municipal wastes enhance the establishment and growth of herbaceous cover on this disturbed high elevation site.

THE USE OF COMPOSTED MUNICIPAL WASTE TO REVEGETATE A HIGH ELEVATION MINE SITE

by

Gary Lynn Vodehnal

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APPROVAL

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Gary Lynn Vodehnal

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

10 Dec 1993 — Frank F. Munshower

Date — Chairperson, Graduate Committee

Approved for the Major Department

12/10/93 — J. M. Paterson

Date — Head, Major Department

Approved for the College of Graduate Studies

12/13/93 — R. L. Brown

Date — Graduate Dean

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ABSTRACT

Mining in alpine and subalpine areas frequently results in surface soil coverings of spoil and overburden that differ substantially from pre-mining soils. These severely disturbed sites frequently require amendments to accelerate the development of desirable nutrient cycles and provide a hospitable growing medium for plants. Composted municipal wastes are becoming more available as greater emphasis is placed on waste reduction at the community level. A market for these waste-generated compost products may be found in the reclamation of disturbed areas. This project evaluated the effects of two types of composted municipal waste and a commercial nitrogen fertilizer on plant establishment, cover, and production. The study site is located at a heap leach gold mine at an elevation of 2,300 meters, 25 kilometers southwest of Helena, Montana. Thirty three plots were established to measure seedling density, vegetative cover, and plant production over two growing seasons. Plots treated with the higher, incorporated rates of EKO sludge compost and Bozeman municipal yard waste compost produced significantly greater plant density, cover, and biomass than the commercial nitrogen fertilizer and unamended top soil treatment. Compost incorporated into the surface horizon produced greater plant cover and biomass than surface applications. After two growing seasons total grass cover and production were significantly greater than all other treatments with the higher rate of incorporated EKO compost. Forb cover and production were significantly greater than all other treatments with the higher rate of incorporated Bozeman compost. Results from this field study suggest that composted municipal wastes enhance the establishment and growth of herbaceous cover on this disturbed high elevation site.

INTRODUCTION

Hard-rock mining in alpine and subalpine areas frequently leaves spoil materials and overburden on the soil surface. These materials differ substantially from pre-mining soils. Removal of developed surface horizons generally results in spoil material at the surface that is both low in organic matter and high in bulk density (Chambers et al. 1987). Numerous studies have demonstrated that amending soils with organic materials, such as sewage sludge and municipal waste compost, increases soil organic matter content and improves soil structure and long-term fertility (Khaleel et al. 1981; Joost et al. 1987; Seaker and Sopper 1988). These municipal wastes have been successful as organic amendments in minespoil and Superfund site reclamation at low elevations in the eastern United States (Plass 1982; Skousen 1988; Garvey and Donovan 1992).

Composted municipal wastes have not been thoroughly tested in arid regions or high elevation environments of the Western United States (Chambers et al. 1988; Fresquez et al. 1990; Brandt and Hendrickson 1991). Researchers studying revegetation techniques at molybdenum mines above timberline in Colorado found the most economical and beneficial soil amendments to achieve sustainable vegetative cover were applications of sewage sludge mixed with wood chips (Brown 1976). Although applying sludge and wood wastes at high elevations has been successful in revegetating mine spoils, nitrogen levels must be carefully balanced to prevent soil microbes from competing with plants for nitrogen during the decomposition process. Composting the sewage sludge and wood wastes at lower elevations could speed decomposition and eliminate some fluctuation in nitrogen cycling (Norland et al. 1991).

The growth and development of municipal composting facilities has expanded rapidly in recent years as communities across the country search for ways to reduce solid waste and increase the life of dwindling landfill space. Commercial composting operations have proven to be a cost effective and environmentally sound recycling technology (Goldstein and Steuteville 1992; Steuteville 1992).

The purpose of this study was to evaluate the effects of two types of municipal compost and a commercial nitrogen fertilizer on vegetation establishment and production at a high-elevation site disturbed by mining.

LITERATURE REVIEW

High-Elevation Ecosystems

High-elevation ecosystems in the United States occur in mountainous terrain of the eleven western states, a small portion of the northeastern states, and Alaska. These high-elevation systems are found near or above tree-line and are characterized by short, cool growing seasons and long, cold winters. Tree-line varies in the western United States from 3,500 m in the Southwest to about 2,000 m in northern Montana (Brown et al. 1978).

Disturbance To The System

High elevation ecosystems are under increasing pressure from activities such as mineral exploration, mining, grazing, recreation, timber harvesting, road construction, and water development. Of the approximately three million hectares (7.4 million acres) of alpine area in the western United States, almost twelve percent has been disturbed and requires rehabilitation (Brown et al. 1978). Because of past abuse and increased development, a major challenge is to develop the technology and skills necessary to return these ecosystems to a natural, self-sustaining state.

Environmental Considerations In Revegetation of High Elevation Sites

Rehabilitation of disturbed high elevation sites is extremely difficult due to severe climatic conditions. Short growing seasons, low temperatures, strong winds, frost action, precipitation extremes, fluctuating soil moisture conditions, and intense solar radiation are a few of the imposing barriers to traditional rehabilitation efforts in these sites. Reclamation efforts are further complicated by extremes in topography and poor accessibility.

The predominant feature of high-elevation environments is the low heat budget that results from short growing seasons (60 to 90 days) and low growing season temperatures (Brown et al. 1978, Guillaume 1984). Temperatures often fall below 0° C and frost may occur periodically during the growing season (Marr and Willard 1970; Brown et al. 1978). Needle ice and frost action injure plants by lifting young seedlings from the soil and exposing roots to desiccation (Brink et al. 1967). The low heat budget requires special adaptations by plants living in the alpine zone (Billings 1974).

Precipitation occurs mainly as snow during the months of September to June. Total effective annual precipitation can be highly variable for different alpine sites due to uneven distribution. Snow drift patterns result from interactions of wind and topography, with lee slopes and depressions receiving higher snow accumulation than windswept ridges.

Strong wind, a characteristic of high-altitude ecosystems, results in severe desiccation of exposed plant parts during both winter and summer (Johnson et al. 1975). Plants on these sites are subject to increased frost damage and severe abrasion by windblown ice and soil particles. Wind also erodes fine soil particles from disturbed sites, reducing water and nutrient-holding capacities (Brown et al. 1978).

High solar radiation flux densities and increased levels of ultraviolet radiation affect the growth and development of higher plants (Caldwell 1968). High radiation levels result in increased soil and plant surface temperatures, which promote high evaporation and drought during the growing season.

Soil Genesis

Many factors influence the development of soils in high-elevation environments. These include parent material, landform and geomorphic processes, as well as vegetation, biological activity, and climate (Brown et al. 1978). The rate of soil development is limited by slow mechanical weathering of the hard and resistant rock types in these regions. Cold temperatures inhibit chemical reactions and biotic activity that contribute to soil genesis. The resulting soils are young, heterogeneous, and weakly developed (Retzer 1974). This heterogeneity of soils complicates rehabilitation efforts, often requiring site specific reclamation solutions.

Well-drained soils are more extensive than poorly drained soils in alpine regions and possess unique characteristics important to successful revegetation efforts. These soils are generally coarse textured with low organic matter content. Severe drought conditions may exist in high-elevation areas because of the reduced water-holding capacities of soils, coupled with periods of low summer rainfall. These soil-water conditions may inhibit plant establishment and growth (Brown et al. 1978).

Severe Soil Disturbance

Mining in high-elevation areas produces spoil materials and overburden which differ from premining soils. Removal of the weakly developed surface soil horizons results in overburden material that is both low in organic matter and high in bulk density (Chambers et al. 1987). Severe disturbance also affects soil structure, organic carbon and nutrient pools, nutrient cycling processes, and moisture holding capacity (Bradshaw and Chadwick 1980; Marrs and Bradshaw 1982; Brandt and Hendrickson 1991).

One of the most severe soil and water problems in high-elevation areas results from the exposure, through disturbance, of pyrites and other sulfide minerals. Natural oxidation of the exposed sulfide minerals with air and water can result in the formation of acid rock drainage. Under these conditions the surface soils, surface water, and groundwater may become very acidic. Acidity may increase the solubility of certain elements, particularly aluminum, to toxic levels. Runoff of these contaminated waters is detrimental to plant communities and seriously degrades water quality and aquatic ecosystems (Brown et al. 1978).

Topsoil Salvage

Salvaging topsoil prior to disturbance is a desirable reclamation activity. Replacing topsoil accelerates soil development by providing a particle size distribution which helps supply adequate water for plant growth, reduces runoff, introduces a variety of plant and microorganism propagules, and encourages faster establishment of nutrient cycles (Schuman and Power 1981). Unfortunately, topsoil is rarely available in sufficient quantities in a high-elevation environment to be effective in the revegetation process (Brown et al. 1978).

Topsoil salvage on high-elevation sites can cause mixing of the shallow A horizon which contains the bulk of the soil's organic carbon and microorganisms with deeper mineral soils. Consequently these disturbances produce cover soil material that lacks structure and is prone to formation of surface crusts after a few periods of rainfall.

Topsoil can be salvaged from adjacent land to replace soil removed during site disturbance. This practice, however, degrades additional areas, is often very costly, and can result in the introduction of plant species potentially detrimental to revegetation. In addition, when topsoil is stored for only a few months before use many essential microbiological constituents are lost (Miller 1984).

Severe soil disturbances produce conditions in which decomposition and nutrient cycling are drastically reduced (Reeder and Sabey 1987; Schuman and Belden 1991). Severely disturbed areas frequently require amendments to increase nutrient availability and develop sustainable nutrient cycles. Nutrient availability is one of the most important factors in revegetation of high-elevation soils. Plant-available-nitrogen is generally deficient in undisturbed alpine soils in comparison to lower-elevation soil systems. This deficiency is the result of cool summer temperatures and restricted microorganism activity in surface soils (Guillaume 1984). Nitrogen supply to plants depends heavily on microbial decomposition and efficient cycling, since nearly all the nitrogen a plant obtains from the soil is derived from organic matter.

<u>Nitrogen Rate</u>

Nitrogen is required in relatively large amounts by plants and is an essential element for plant metabolism. Impaired nitrogen supply is the most important factor limiting ecosystem development and the attainment of self-sustaining vegetation. In soils, most of the total available nitrogen

(>95%) exists as organic nitrogen (Marrs and Bradshaw 1982) with low levels (<1%) in the form of nitrate or ammonia nitrogen (Faust and Nimlos 1968). In colder climates of high-elevation areas, decomposition rates are very slow. Consequently, there must be a large nitrogen reservoir to provide a sufficient supply through mineralization to meet annual vegetation requirements. The total nitrogen reserve and rate of mineralization are critical to sustained plant growth in disturbed high-elevation systems.

Legumes add significant levels of nitrogen to geologic materials through nitrogen fixation. They help reestablish pathways for rapid nitrogen cycling (Reeder 1990). Several problems are posed by including agronomic legume species (i.e., Trifolium spp.) in a reclamation seed mix for high-elevation sites. High levels of calcium and phosphorus must be added to disturbed soils to maintain a productive legume population (Marrs and Bradshaw 1982). The use of introduced legume species may not be permitted if state reclamation laws require the use of native species. Legumes are also sensitive to some heavy-metal toxicities, phosphorus availability, and competition from many grass species (Plass 1982).

Inorganic Fertilizers

A deficiency of plant-available nitrogen can limit plant growth and long-term stability of land disturbed by surface mining. Deficiencies arise because disturbance drastically alters the flow of nitrogen through the soil-plant-microbial ecosystem. The availability of nutrients, especially nitrogen, depends on the severity of the disturbance (Tilman 1982). A major reclamation goal has been to achieve stabilization of the disturbed site with a desirable plant community that requires little or no long-term fertilization inputs. Hopefully, the community will maintain a level of productivity comparable to that existing before disturbance (Woodmansee et al. 1978). Development of a self-sustaining nitrogen cycle involves both accumulation of nitrogen within the system and efficient cycling of this nitrogen reserve (Marrs and Bradshaw 1982). A minimum nitrogen supply of 1000 kg/ha to develop a self-sustaining nitrogen cycle was recommended by these authors for China clay waste. Some disturbed land may require decades or centuries to accumulate this much nitrogen naturally and evolve toward a stable nutrient cycle (Reeder 1985).

Conventional rehabilitation methods at high elevation sites rely on the use of commercial nitrogen, phosphorous, and potassium fertilizers to increase available nutrients for plant growth and survival (Brown et al. 1978). With low levels of available nitrogen in high-elevation topsoil, a rapid response would be expected from application of small amounts of nitrogen fertilizer. This has not been the case, however. In a study carried out at a high-elevation site in Colorado, 270 kg of NH_4NO_3 (ammonium nitrate)/ha were required before a plant response was noted (Faust and Nimlos 1968). Scott and Billings (1964) reported similar results in the Medicine Bow Range of Wyoming. Application rates of up to 111 kg of nitrogen (equivalent)/ha in bulk fertilizer were absolutely essential for successful and rapid establishment of plants on high-alpine sites (Brown et. al. 1978). However, Brown et al.(1984) found that inorganic fertilizers were not reliable sources of nutrients for plant growth in a high-alpine area unless applied repeatedly over long time periods. Berg and Barrau (1978) indicate that for best results on a disturbed high-elevation site, nitrogen should be applied at a rate of 60 pounds per acre per year for at least 4 consecutive years. Chambers et al. (1987) reported that the residual quantities of nitrogen, phosphorus, and potassium on revegetated alpine areas in Montana decreased rapidly after fertilizer application. Incorporation of organic matter was viewed as an important step towards retention of these elements in a viable system of nutrient cycling.

In some cases higher seedling mortality was noted on fertilizer plots in disturbed alpine sites because of an initial pulse of nitrogen and phosphorus, followed by a rapid decline in nitrogen. This decline in fertility following a nutrient pulse can result in decreased nutrient absorption, photosynthesis, and growth, and in turn, cause greater susceptibility to other stresses (Chapin 1980).

Reeder (1990) stated that inorganic nitrogen fertilizer added to mined lands was more prone to leaching and volatilization losses because plant and microbial communities were less active after disturbance. This raises the concern of the impact on surface and ground waters of increased dissolved nitrogen levels related to heavy nutrient loading on disturbed sites.

Rennick et al. (1984) did not recommend using inorganic fertilizers on topsoiled coal spoils in Montana because of increased invasion by weedy species and a loss of plant community diversity. Brown et al. (1984) stated that high seeding rates and heavy application rates of inorganic fertilizer could produce closed plant communities and impede successional development in alpine ecosystems.

Organic Matter

Soil organic matter consists of plant and animal residues in various stages of decomposition, living soil organisms, and substances synthesized by these organisms. This material is important to the development of mineral soils and is one of the major keys to soil productivity. Soils differ in organic matter content from region to region. Semiarid areas usually have topsoil with less than 2% organic matter.

The chemical composition of soil organic matter is categorized in three major groups: polysaccharides, lignins and proteins. These three classes of materials are sources of food for soil micro-organisms (Ludwick 1990). Organic matter is primarily carbon (approximately 58% by weight) and contains a large reservoir of essential plant nutrients (Tisdale and Nelson 1985). The concentration of nitrogen in plant material is usually greater than 1% and may exceed 3% (Reeder and Sabey 1987).

Organic matter content of soils directly affects moisture-holding capacity by increasing water absorption and retention (Brandt and Hendrickson 1991). It also enhances nutrient availability by increasing cation exchange capacity, and provides a steady supply of plant nutrients through decomposition and mineralization (Smith et al. 1987).

High seedling mortality has been attributed to the formation of needle ice and soil drought conditions at high-elevation sites (Roach and Marchand 1984). Cochran (1969) found that organic amendments enhanced seedling establishment by decreasing soil water loss and increasing soil surface temperatures. Organic amendments also alter surface characteristics which help prevent surface wind erosion of soil and seeds.

Incorporating organic matter into mineral soils and spoils can increase plant growth (Joost et al. 1987; Smith et al. 1987; Ludwick 1990). Brown et al. (1978) recommended application rates of 2,000 to 4,000 kg/ha^{-1} of organic matter to improve water and nutrient availability in xeric, sterile alpine spoils. However, a cost effective and environmentally acceptable source of organic matter suitable for high-elevation reclamation projects can be difficult to find.

Benefits of Compost

The benefits of composted municipal wastes on disturbed sites are derived primarily from the compost's structure, organic carbon pool, nutrient content and form, and microbiological inocula (Brandt and Hendrickson 1991). The relative contributions of each type of compost to soil characteristics and plant growth will vary with the materials and bulking agents used in the composting process. Compost dry matter based on plant and animal wastes contain a full range of plant macro- and micronutrients generally suited for plant growth. All composts provide a large amount of degraded organic matter which may improve the friability of fine-textured soils and the moisture-holding capacity of coarse-textured soils (Bradshaw and Chadwick 1980).

One of the principal benefits of compost additions to disturbed soils is the initiation of nutrient cycling. This results from the inoculation into sterile soils of microbial decomposers present in the compost. The supply of mineral nitrogen in soils is constantly replenished by microbial mineralization of soil organic matter. In this process, certain soil microorganisms use organic substances as an energy source and nitrogen from the organic material as a building block for microorganism protein. Dead microorganisms subsequently decay and release nitrogen for microorganism and plant use. Studies of compost and municipal sludge amendments to soils have documented increased soil microbial biomass and nutrient cycling (Fresquez and Lindemann 1982; Whitford et al. 1990). Microbial processes are so important to soil recovery that the activity of microorganisms may be used as an index for the progress of soil genesis in minespoils (Seaker and Sopper 1988).

The microbial decomposition of organic matter is also one of the most important factors in soil structure development. Soils with good structure provide the best conditions for supplying water and nutrients to plants. The best water and nutrient regimes occur in soils with granular structure with aggregate sizes from 1 to 2 mm (Smith et al. 1987). Brandt and Hendrickson (1991) stated that additions of 25% compost by volume could alter physical characteristics of soils. Organic material has little effect on soil structure, however, unless microbial activity produces stable soil aggregation. Fungi and actinomycetous produce mycelia and have metabolic processes that synthesize complex organic molecules. These decomposition products, in combination with the mechanical binding action of cells and filaments from microorganisms, produce stable soil aggregates.

Another important benefit of compost additions to disturbed soils is the inoculation into sterile soils of symbiotic mycorrhiza (Brandt and Hendrickson 1991). These organisms form symbiotic associations with root systems of many plants and their presence is crucial for water and mineral uptake by some higher plants (Williams 1979; Whitford et al. 1990).

Surface mining can disrupt mycorrhiza and other microorganism populations in soil when plant communities are temporarily destroyed. Microbial population disruption is increased when top-soils are stored for long periods of time or mixed with spoil and subsoil material. Repopulation of the microbial biomass in such areas can be very slow because fungi and bacteria do not readily adapt to chemical and physical changes in disturbed soils (Smith et al. 1987).

Addition of composts, which are high in organic matter content, can improve water infiltration, reduce evaporation, improve drainage in fine-textured soils, and encourage more extensive and deeper root systems (Brandt and Hendrickson 1991). Other organic amendments, such as straw and wood-fiber mulches, can also have positive effects on soil structure when they are incorporated into the soil column (Schuman and Belden 1991). These amendments, however, may be low in those nutrients commonly supplied by compost. Their high carbon content could actually decrease nitrogen availability for plants because the amendments stimulate microorganism growth rates with a subsequent increase in nitrogen uptake. (Simms 1990). Consequently, rates of decomposition and nutrient cycling in soils receiving only mulch will generally be lower than compost-treated soils (Brandt and Hendrickson 1991).

Sewage Sludge and Composted Municipal Waste in Reclamation

Numerous studies have shown that amending soils with organic materials such as sewage sludge increases soil organic matter content, and improves soil structure and long-term fertility (Bradshaw and Chadwick 1980; Khaleel et al., 1981; Joost et al. 1987; Simms 1990). Many of these studies were carried out on agricultural lands, but sewage sludge has also been extremely successful when used as an organic amendment in minespoil reclamation (Hortenstine and Rothwell 1972; Seaker and Sopper 1988; Skousen 1988).

Researchers in Philadelphia, Pennsylvania used a "mine mix" of 50 percent dewatered sludge and 50 percent sludge compost to successfully reclaim strip mined lands (Alpert and Segall 1990). Sabey et al. (1980) demonstrated the benefits of sewage sludge in the reclamation of disturbed oil shale lands in northwestern Colorado. Sewage sludge also enhanced the growth of native shrubs in spoils of a copper mine in Utah (Sabey et al. 1990). Norland et al. (1991) utilized composted municipal waste to increase vegetative establishment on coarse taconite tailing on Minnesota's Mesabi iron range. Four applications of municipal waste compost, applied during a two year period, significantly improved soil nutrient characteristics and increased plant growth on sterile phosphate sand tailings in Florida (Hortenstine and Rothwell 1972).

Several researchers found that municipal sludge could be used to successfully revegetate strip-mined land in Pennsylvania (Sopper and Kerr 1981; Seaker and Sopper 1988). Repeated sludge applications had no adverse effects on vegetation, soil, or groundwater quality and there was little risk to animal or human health from heavy-metal contamination.

Amendments such as sewage sludge and composted municipal waste have proven valuable in reducing metal toxicities in acid tailings. A combination of sewage sludge and fly ash were used to revegetate an acidic and heavy metal contaminated superfund site in Pennsylvania (Garvey and Donovan 1992). Plass (1982) successfully revegetated acidic wastes (pH of 4.0) by applying 20 metric tons of organic matter per hectare. Mushroom compost and paper-mill sludge were used to successfully revegetate acidic (pH 3.3 to 4.1) coal-mine spoils in southeastern Ohio (Vogel and Rothwell 1985).

Three Amax Inc. molybdenum mines at timberline along the continental divide in Colorado have had active reclamation programs for years. Researchers have found that a mature soil is prerequisite to achieving self-sustaining vegetation. The most economical and beneficial soil amendments were an initial application of 44.8 metric tons per hectare of both sewage sludge and wood-chips, followed two or three years later by an additional 22.4 metric tons per hectare of sludge (Brown

1976). Although this procedure has been successful, nitrogen levels must be carefully balanced. Soil microbes consume more nitrogen than plants during decomposition, which may result in soil nitrogen deficiencies. A compost is more chemically stable and less likely to mobilize nitrogen when added to soil, after it has decomposed over a longer period of time (Sikora and Sowers 1985). Composting the sewage sludge and wood wastes at lower elevations and transporting the finished product to a high-elevation site could speed decomposition and eliminate some fluctuation in nitrogen cycling.

Wood-chip/municipal sludge composts were tested in revegetation experiments in an arid region of southeastern Washington. Compost was incorporated into soils that failed to support growth the previous year. Plant survival and growth on the composted sites was more than twice that of the untreated controls. Grass density on the composted sites was three to five times greater than controls. Sludge compost treatments also produced greater revegetative success than combinations of straw mulch and low-rates of fertilizers (Brandt and Hendrickson 1991).

A review of the literature substantiates the idea that composted municipal wastes have properties that are beneficial in reclaiming mining disturbances. This project was designed to determine whether this increasingly available waste product has a practical use in restoring alpine and subalpine ecosystems.

Compost Availability

The growth and development of sludge and yard waste composting facilities has expanded rapidly in recent years as communities across the country search for ways to reduce solid waste and increase the life spans of dwindling landfill space. There were an estimated 800 to 1,000 municipal yard waste composting facilities in the United States in 1988 with the number growing steadily (Glenn 1988). In 1987, there were 90 sludge composting projects nationwide, with 61 operating plants. In 1989 there were 227 sludge composting projects, and 119 operating plants (Goldstein and Riggle, 1989). Commercial composting operations have proven themselves to be a cost effective and environmentally sound recycling technology (Taylor 1989).

Although there has been substantial research on the use of sewage sludge and compost in mine reclamation at low elevations, use of sewage sludge compost at high-elevation sites in the Western United States has not been thoroughly and scientifically tested. Further investigation is needed to evaluate how different types of municipal compost effect the establishment of vegetation on disturbed high-elevation sites.

MATERIALS AND METHODS

Site Description

The Basin Creek gold mine, a heap leach operation, is located approximately 25 km southwest of Helena, Montana (Figure 1). Operation of the mine will result in the disturbance of approximately 156 ha. The mine includes public and private land in the Deerlodge and Helena National Forests and straddles the continental divide at elevations from 2,260 to 2,380 m (Figure 1).

Soils in the project area are primarily gravelly and sandy loams in the early stages of development with pH values from 4.5 to 7.5. Parent materials consist of quartz monzonite at lower elevations and porous lithic tuff and rhyolite flows at higher elevations. Prior to disturbance the soil at the study site was classified as a Typic Cryoboralf, coarse loamy, mixed (Noel 1989). Mean annual precipitation averages 760 mm per year.

The subalpine site is dominated by dense stands of lodgepole pine (Pinus contorta) with common beargrass (Xerophylum tenax) and grouse whortleberry (Vaccinium scoparium) the dominate ground cover. Mining disturbance completely destroyed the plant community which previously occupied the study site.

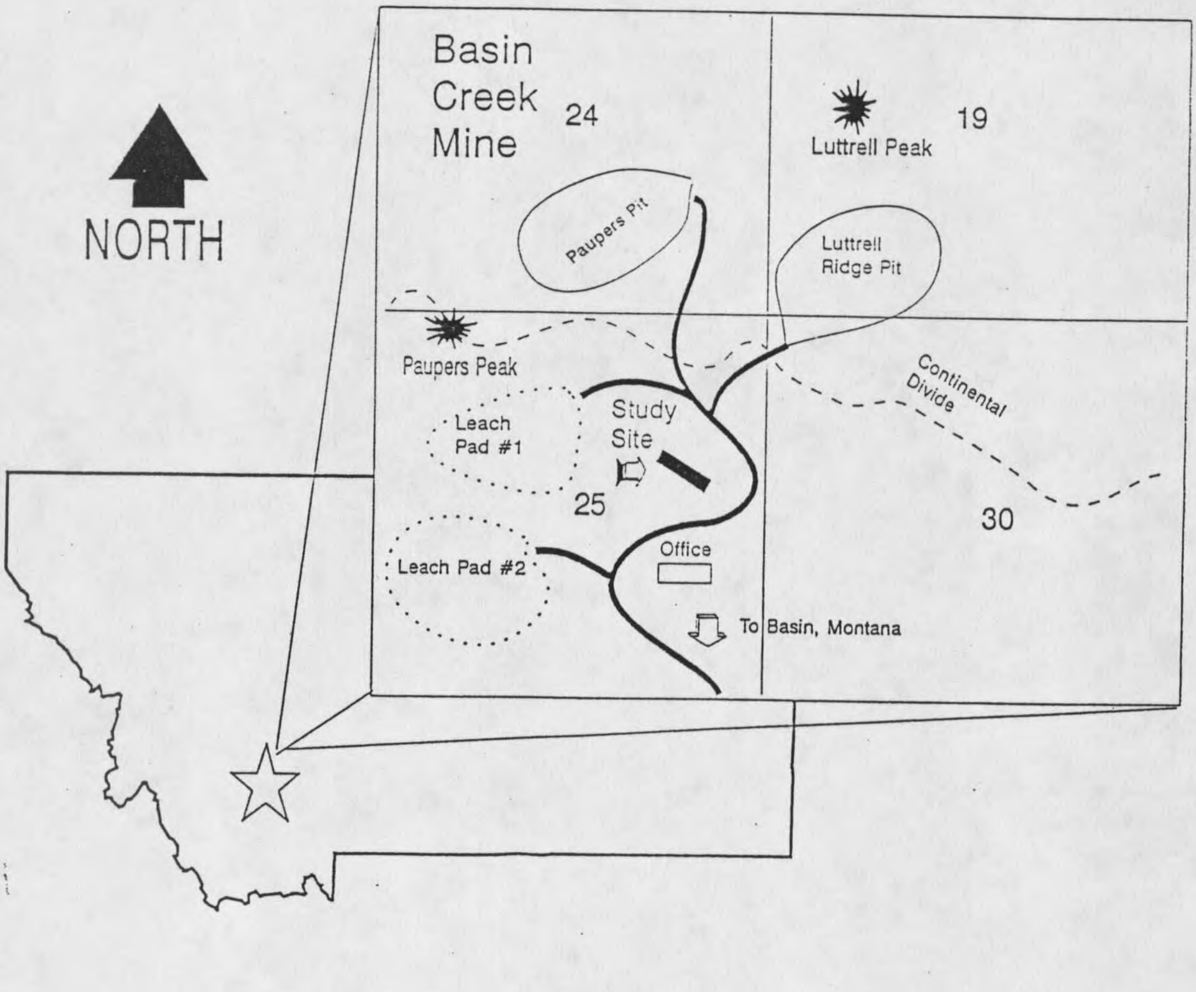

Figure 1. Location of Basin Creek Mine study site.

Field Plot Design

In late June of 1991 project implementation began on a 0.5 ha area of the mine, previously used as a haul road (Figure 1). The area was recontoured to a 1 to 8% grade with a southwesterly exposure. Salvaged topsoil was spread over the area to a depth of 15 to 20 cm. Plots with dimensions of 3 by 3 m were established in a randomized block design (Figure 2). One meter buffer zones were maintained between all plots. Nine treatments and two controls per block were replicated three times for a total of 33 plots.

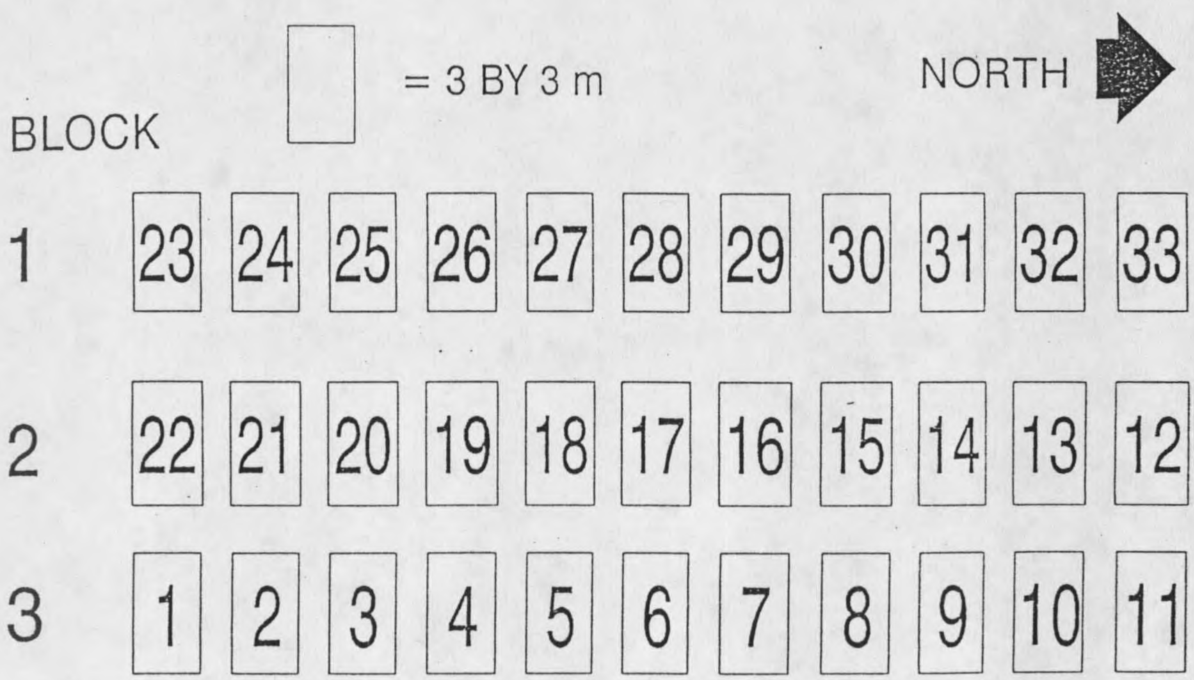

Figure 2. Randomized block design for treatments.

Amendment Recommendations

The Basin Creek Mine began using 9.5 Mg/ha of surface applied sewage sludge compost (EKO Compost) as an amendment during the fall of 1990. This application rate was based on recommendations from greenhouse vegetation trials conducted for the mine (Noel 1990). Soil crusting had been identified as a possible factor contributing to poor vegetative growth on reclaimed areas at the mine. In these trials, incorporated compost appeared to increase vegetative yields and prevent soil crusting. The rates of compost used in this study were based on recommendations from other studies, (Plass 1982; Vogel and Rothwell 1985; Seaker and Sopper 1988; Brandt and Hendrickson 1991). EKO compost and the Bozeman compost were selected for use in this study because they were the only composts available in the region surrounding the Basin Creek Mine, and were produced in large enough quantities to be effective in the reclamation of a disturbed mine site.

Application Rates And Methods

Sewage sludge compost (EKO) is produced commercially in Missoula, Montana. The compost operation is located adjacent to the municipal sewage treatment facility and utilizes sewage sludge combined with wood product wastes and yard debris. The three-phase composting process is completed in nine months. The final product is screened; 1 cm for gardening, 2.2 cm for mining and a double 1 cm screening for hydromulchers. Mine compost was transported in cubic yard bags to the mine site.

EKO compost was applied at two rates, 76 Mg/ha and 152 Mg/ha. This is equivalent to compost being spread at 1.25 cm and 2.5 cm thick layer over the surface of the plots. The two EKO compost rates of 76 Mg/ha and 152 Mg/ha were surface applied and both rates were incorporated to a depth of 10 cm with a rototiller.

Bozeman Compost (BOZ) is produced by the municipality of Bozeman, Montana at the local landfill. The compost used in this study was made up of an estimated 30% grass clippings, 30% leaves, and a 40% combination of straw, hay, manure, hedge trimmings, and wood chips. Finished compost is produced in 20 months and is provided free to the public or used as a soil amendment in rehabilitation of the landfill site.

Bozeman compost, like EKO, was applied at two rates; 76 Mg/ha and 152 Mg/ha. This is equivalent to the compost being spread 1.25 cm and 2.5 cm thick over the surface of the plots. The compost was incorporated to a depth of 10 cm with a rototiller. No surface applications were made with this amendment.

Mine Combo (MINE CMBO) is the name given to a combination of amendments used by Basin Creek Mine. This mine applies the amendments with a hydromulcher for revegetation projects. A hydromulcher was not available for this study, consequently replicated amendment rates were broadcast by hand.

Mine Combo amendments consist of EKO compost double-screened through a 1 cm mesh and hydromulched at 9.5 Mg/ha. This is equivalent to compost being spread 1.6 mm over the surface of the plots. Pro-Rich dehydrated poultry waste and Silva-Fiber, a wood fiber mulch, were combined with the compost. Application rates were 112 kg/ha Pro-Rich dehydrated poultry waste with $N-P_2O_5-K_2O$ content of 14-5-5 percent respectively and 2.2 Mg/ha of Silva-Fiber.

Rates of nitrate fertilizer (FERT), were based on the total Kjeldahl Nitrogen (TKN) analysis of EKO Compost. Fertilizer rates were equivalent to 0.7% total nitrogen by weight, present in the two rates of EKO Compost, 76 Mg/ha and 152 Mg/ha, which were applied in this study. This resulted in fertilizer application rates of 0.51 Mg/ha and 1.02 Mg/ha. The granulated fertilizer was broadcast by hand and raked into the soil surface.

Two controls (CONT) were used. CONT I had no amendments or seed and CONT II was seeded with the Basin Creek seed mix. No amendments were added to CONT II, however (Table 1).

Seed Mix and Rate

The plots were rototilled to a depth of 7 to 10 cm for seed bed preparation. All plots were broadcast seeded by hand with the Basin Creek Mine seed mix (Table 2). Seed was lightly raked into the amended surface soil.

Table 1. Treatments and amendment rates applied in June 1991.

TREATMENT	PLOT NUMBER	AMENDMENT RATE	METHOD
EKO 1I	11,21,29	2.5 cm (152 Mg/ha)	Incorporated
EKO 1S	5,18,30	2.5 cm (152 Mg/ha)	Surface
EKO .5I	9,14,26	1.25 cm (76 Mg/ha)	Incorporated
EKO .5S	3,15,25	1.25 cm (76 Mg/ha)	Surface
BOZ I1	2,19,33	2.5 cm (152 Mg/ha)	Incorporated
BOZ .5I	7,12,24	1.25 cm (76 Mg/ha)	Incorporated
MINCMBO	1,16,23	Basin Reveg Mix	Surface
FERT 1	8,17,32	NH_4NO^3 1.02 Mg/ha	Surface
FERT .5	6,13,22	NH_4 NO^3 0.51 Mg/ha	Surface
CONT I	10,27,31	No Amendments No Seed	None
CONT II	4,20,28	No Amendments Seeded	None

Soil and Compost Sampling

Three samples of salvaged topsoil and three compost samples used in this study were collected in June, 1991 at the Basin Creek Mine. Samples were taken randomly from stock-piled topsoil and bagged compost. Physical and chemical characteristics of these samples were analyzed by the soil laboratory at Montana State University in Bozeman, Montana. The parameters analyzed were pH (acidity) (McLean 1982), EC (electrical conductivity) (Rhoades 1982), organic matter (Sims and Haby 1971), K (potassium) (Knudsen et al. 1982), P (phosphorus) (Olsen and Dean 1965), NO_3 (nitrate) (Simms and

Table 2. Basin Creek Mine seed mix and rate.

Common Name	Scientific Name[1]	kg/ha[2]
streambank wheatgrass (v. Sodar)	Agropyron riparium Scribn. & Smith	7.84
slender wheatgrass (v. Revenue)	Elymus trachycaulum (Link) Gould	2.80
redtop	Agrostis stolonifera L.	.28
meadow foxtail	Alopecurus pratensis L.	2.80
mountain brome	Bromus carinatus Hook. & Arn.	3.92
tufted hairgrass	Deschampsia caespitosa L.	.56
tall fescue	Festuca arundinacea Schreb.	3.92
sheep fescue	Festuca ovina L.	1.40
Canada bluegrass	Poa compressa L.	.28
cicer milkvetch	Astragalus cicer L.	1.40
birdsfoot trefoil	Lotus corniculatus L.	1.40
white dutch clover	Trifolium repens L.	1.40
	Total	28.00

[1] Rumely and Lavin 1991

[2] (PLS) Pure Live Seed

Jackson 1971), and TKN (Bremmer and Mulvaney 1982). The Modified Day Mechanical Technique was used in the textural analysis of these samples (Day 1965).

Soil samples were collected in September of 1992 on three of the amended study plots which appeared to have the greatest vegetative cover and production, (Plot 9, EKO 0.5 I; Plot 11, EKO 1 I; Plot 19 BOZ 1 I). Three soil samples were also collected in an area adjacent to the study site. This area had been topsoiled but had not been amended. These samples were taken from the surface to a depth of 10 cm.

Penetrometer Measurements

To quantify soil crust strength at the study site, pocket penetrometer measurements were made on July 20 and August 31, 1992. Penetrometers measure the resistance of soil to vertical penetration in kilograms per square centimeter. Ten randomly selected locations per plot were sampled.

Precipitation Measurements

The Basin Creek Mine maintains a meteorological station approximately three kilometers from the study site. Mean annual precipitation between 1988 and 1992 was recorded at this station. Daily records and monthly summaries for 1988-1992 are located in Appendix A. No soil moisture information was gathered at the time penetrometer readings were taken.

Vegetative Sampling

Seedling density was examined at three to six week intervals in July, August, and September 1991. Density was estimated by counting seedling numbers inside ten 20 by 50 cm frames located at pre-selected points along diagonal transects in each plot (Figure 3). Plant cover was determined in September 1992. Cover estimates were made to the nearest percent. Cover was estimated in five 20 by 50 cm frames pre-selected along transect (1) within each plot. Above-ground plant production was determined in September 1992 by clipping above-ground biomass in five 20 by 50 cm frames located along transect (1) in each test plot.

Transect one (1) was established by stretching a string line from the southeast to the northwest corner of each plot. Five pre-selected points were marked on the line at intervals of 104 cm, 126 cm, 147 cm, 170 cm and 191 cm. Transect two (2) used the same spacing as one (1), however, the line was stretched from the northeast to the southwest corner of each plot.

Nonseeded Plants

Nonseeded plant species were collected from the study plots during the two field seasons, 1991 and 1992. These plants were not part of the seed mix used at the Basin Creek Mine or in this experiment.

Statistical Analysis

All data sets were analyzed using a one-way analysis of variance comparison test on means (Student-Newman-Keuls). Multiple mean comparison was based on Least Significant Differences (LSD) at a significance level of 0.05.

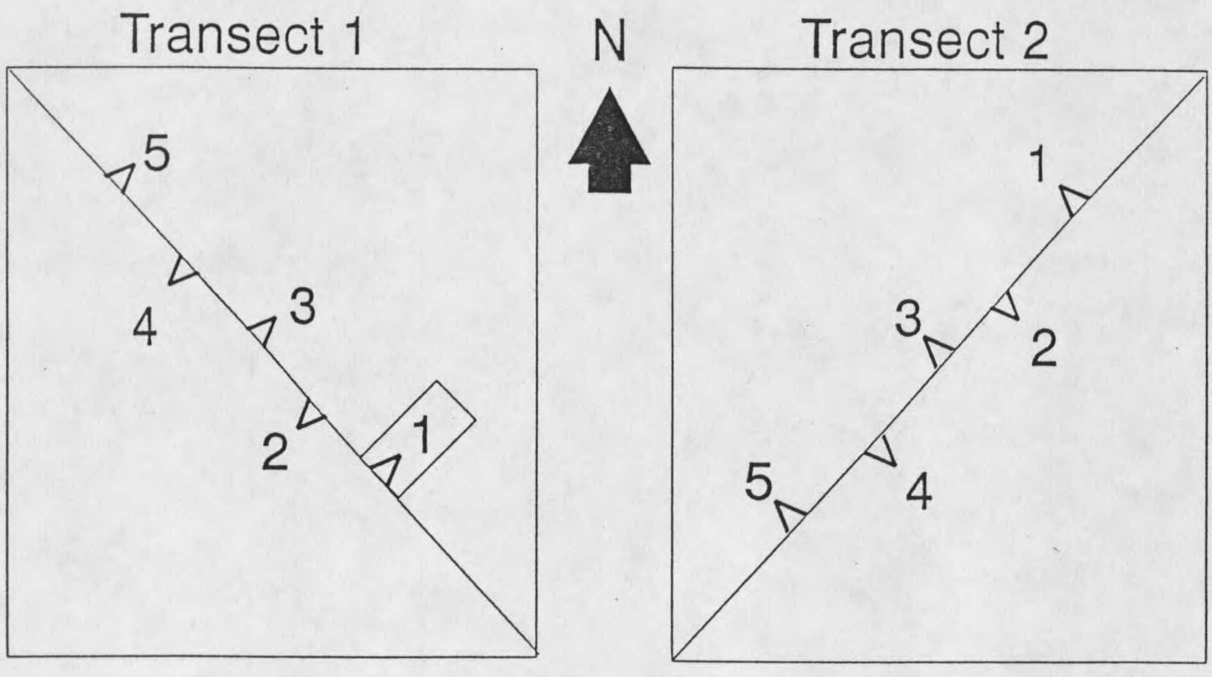

Figure 3. Vegetative transect design.

RESULTS AND DISCUSSION

Soil and Compost Sampling

Properties of Compost and Topsoil

Data from compost samples had a higher trend in pH, EC, organic matter and nutrient content than the topsoil samples (Table 3). Several chemical differences were found between the two composts. Bozeman compost had higher pH, EC, and potassium content than EKO compost. However, greater organic matter content and phosphorus levels were found in EKO compost. These variations could be attributed to differences in the composted materials and processes.

Table 3. Properties of salvaged topsoil and compost amendments(mean of three samples).

Amendments	pH	EC mmhos/cm	Organic Matter %	Soil K mg/kg	Soil P mg/kg	NO_3-N mg/kg	TKN %
Topsoil	4.9	0.03	2.5	117	12.6	<0.1	0.036
EKO	6.6	1.74	54.7	955	359.8	420.2	0.669
BOZ	7.4	2.50	9.2*	4080	207.5	444.0	0.563

* Normal values are 30-60% Organic Matter.

Properties of Surface Soils

Soil sample data from compost plots, collected in September 1992, followed a trend toward higher pH, EC, organic matter and nutrient content than the unamended topsoil samples. These differences may be attributed to the addition of the compost amendment to the topsoil material.

The most apparent differences between compost treatments were higher pH and phosphorus levels for the heavier rate of incorporated Bozeman compost in comparison with the two EKO compost treatments (Table 4). Composted EKO plots, however, had higher organic matter content and soil potassium levels than the Bozeman compost treatment. These variations are most likely the result of differences in materials and bulking agents used in the composting process (Table 4).

Table 4. Physical and chemical properties of surface materials (mean of three samples).

	pH	EC	Organic Matter	Soil K	Soil P	NO_3-N	TKN
Treatments		mmhos/cm	%	mg/kg	mg/kg	mg/kg	%
EKO 0.5I	5.8	0.11	19.47	174	139.3	2.5	0.467
EKO 1I	5.8	0.12	19.19	194	137.6	1.8	0.431
BOZ 1I	7.8	0.17	6.97	492	74.2	1.3	0.355
TOPSOIL	5.3	0.05	2.91	114	24.9	<.1	0.057

Textural Analysis

Prior to disturbance the soil at the study site was classified as a Typic Cryoboralf, coarse loamy, mixed (Noel 1989). This soil was salvaged from the site and reapplied to a depth of 15 to 20 cm. Textural analyses of the samples (Table 5) indicated that the compost treated plots had a loamy texture, and the unamended topsoiled area a sandy loam texture. The topsoil samples had higher sand content and lower silt and clay content than the compost amended samples. Textural differences between the unamended and amended topsoil material may be attributed to added compost.

Table 5. Textural analysis of soil and compost samples.

Surface Soil Samples	Sand %	Silt %	Clay %	Texture
EKO .5 I	48	36	16	loam
EKO 1 I	49	35	16	loam
BOZ 1 I	45	38	17	loam
TOPSOIL	54	32	14	sandy loam

Soil Crusting

Minesoil crusting is the consolidation of surface particles due to externally applied forces. Crust formation begins with minesoil breakdown due to the force supplied by raindrop impact. This impact causes the translocation of fine particles to the upper 1 to 2 mm layer. Radiant energy of the sun dries this surface layer and cements the translocated particles into a hard crust (Dollhopf and Postle 1988, McIntyre 1958).

It was hypothesized that soil crusting at the Basin Creek Mine contributed to poor revegetative success on several previously reclaimed sites and that addition of organic matter could alleviate this problem. This hypothesis was based on green house studies contracted by the mine (Noel 1990), literature review of reclamation problems at high-elevation sites, and observations made at the study site during the 1991 field season. Parady (1981) found that organic matter addition decreased crust strength by aiding formation of stable soil aggregates, which decreased clay adhesion in the sand fraction.

Penetrometer Measurements

No significant differences were found in July penetrometer measurements which would indicate a trend towards weaker crusts with the addition of a compost amendment (Table 6). In August the EKO 2.5 cm surface and incorporated treatments did have significantly less crust strength than all other treatments. All compost treatments had less crust strength than the fertilizer treatments and controls with the exception of the Mine Combo treatment. No correlations were found by regressing penetrometer readings against vegetative density, cover, or production data.

Table 6. Mean penetrometer readings from July and August 1992 in kg/cm^2. (N=30)

Treatment	July Mean	± 1 S.D.	August Mean	± 1 S.D.
CONT II	3.73a[1]	0.98	3.80a[1]	0.95
MINECMB	3.56ab	0.95	4.03a	0.74
EKO .5S	3.38ab	1.07	3.04a	0.97
BOZ 1I	3.08ab	0.97	3.18a	1.09
FERT 1	3.06ab	1.09	3.49a	1.11
BOZ .5I	2.93bc	0.90	3.43a	0.94
EKO .5I	2.89bc	0.77	3.00a	0.96
CONT I	2.86bc	1.13	3.64a	0.93
FERT .5	2.83bc	1.14	3.51a	1.07
EKO 1I	2.28c	0.79	2.04b	0.82
EKO 1S	2.24c	0.79	1.75b	0.74

[1] Means followed by the same letter in the same column indicate no significant difference (P=0.05).

Penetrometer means for August were consistently higher than July readings. Parady (1981) found that crust strength increased with decreasing moisture content. No soil moisture information was gathered at the time penetrometer readings were taken. However, daily precipitation data (Appendix A) from the Basin Creek Mine indicates less precipitation fell in the time period prior to the August penetrometer readings than in the same time period prior to the July readings.

Precipitation

Forty three days elapsed between penetrometer measurements taken on July 20th and August 31, 1992. During that period of time 36.8 mm of precipitation were recorded. In the 43 days prior to July 20, 1992 a total of 198.1 mm of precipitation fell at the mine site. This variation in precipitation between the time periods when penetrometer readings were taken may explain the changes in crust strength.

Precipitation was below the five year average for the two years in which this study was conducted (Table 7). Extreme variability in climatic conditions over the short duration of this study make it extremely difficult to correlate precipitation and plant growth. Brown et al. (1984) found strong variability in climatic conditions at a high-elevation site from year to year. These researchers suspected that variation in precipitation, snowpack accumulation, and temperature during the growing season had a greater influence on vegetative growth than the fertilizer treatments being applied.

Table 7. Mean annual precipitation from 1988-1992 in mm.

Year	1988	1989	1990	1991	1992	5 Year/Mean
Precip.	672	818	582	536	435	594

Nonseeded Plants

These introduced weedy species could have been transported to the site through a variety of means (Table 8). The study site is a reclaimed haul road with an active haul road 30 m from the study plots. Passing vehicles and heavy equipment working on the mine may have dispersed the seeds. The commercial seed mix or Bozeman and EKO composts could also be sources of contamination.

The destruction of weed seeds and plant pathogens in the composting process is dependent on the heat of decomposition generated by the composting operation. Compost must be exposed to high temperatures (66-71°C) in the interior of the pile long enough to destroy viable weed seeds. Since all parts of the pile may not achieve this temperature range, the introduction of large quantities of weedy plants into compost piles should be avoided (Rosen et al. 1989).

Table 8. Nonseeded plants (Hitchcock and Cronquist 1974).

Common Name	Scientific Name	Plot	Treatment
cheatgrass	Bromus tectorum L.	12	BOZ .5 I
cheatgrass	Bromus tectorum L.	19	BOZ 1 I
mustard	Descurainia sophia L.	07	BOZ .5 I
pale alyssum	Alyssum alyssoides L.	12	BOZ .5 I
pennycress	Thlaspi arvense L.	24	BOZ .5 I
bull thistle	Cirsium vulgare Savi.	30	EKO 1 I
pigweed	Amaranthus retroflexus L.	30	EKO 1 I

Density

In September 1991, the MINECOMBO treatment had significantly greater grass and forb seedling densities than all other treatments. All compost amendments had significantly greater grass and forb seedling densities than the controls and fertilizer treatments (Table 9).

Table 9. Mean seedling density (m_2) in September, 1991 (N=15).

Treatment	Grass Seedlings Mean[1]	± 1 S.D.	Forb Seedlings Mean[1]	± 1 S.D.
MINECOMBO	301a	19.4	94a	12.4
BOZ 1I	233b	13.9	54b	4.4
EKO 1I	218b	12.1	33b	2.8
EKO .5S	190b	9.4	48b	6.1
EKO .5I	185b	12.1	40b	4.7
EKO 1S	178b	12.9	15b	2.1
BOZ .5I	170b	10.8	41b	3.6
CONT II	97c	5.1	5b	0.6
FERT .5	41c	2.7	0b	0.0
CONT I	33c	2.3	0b	0.0
FERT 1	30c	3.5	0b	0.0

[1] Means followed by the same letter in the same column have no significant difference (P=0.05).

Cover

Cover is an important factor in successful revegetation. It is an indicator of how much erosion protection the surface receives from plant leaves. Cover data collected in September

1992 are presented in Table 10. Plots treated with Bozeman compost yielded significantly greater total cover than other treatments when applied at a rate of 2.5 cm and incorporated 7 to 10 cm. Total grass cover on plots in which 2.5 cm of EKO compost were incorporated was significantly higher than on the other plots. Total forb cover was significantly greater on plots with 2.5 cm of incorporated Bozeman compost. Incorporated compost treatments produced greater cover than surface applied compost, fertilizer, and control treatments (Table 10).

Table 10. Plant cover in September, 1992 (N=15).

Treatment	Total Cover(%)	± 1 S.D.	Grass Cover(%)	± 1 S.D.	Forb Cover(%)	± 1 S.D.
BOZ 1I	50.5a[1]	24.3	20.6bc	12.1	29.9a	28.7
EKO 1I	40.1ab	12.7	39.1a	13.8	1.5b	3.0
EKO .5I	28.9bc	20.9	26.1ab	19.2	2.8b	6.7
BOZ .5I	26.6bc	17.2	15.3bc	8.2	11.4b	15.0
EKO 1S	25.3bc	15.9	25.1ab	15.8	0.0b	0.5
MINECMB	21.0bcd	18.9	20.1bc	18.3	0.8b	1.8
EKO .5S	19.7bcd	9.3	18.9bc	8.8	0.3b	1.5
FERT .5	11.7cd	5.8	11.5bc	5.9	0.1b	1.0
FERT 1	7.9cd	9.0	7.9bc	9.0	0.0b	0.0
CONT II	4.5cd	4.5	4.5bc	4.5	0.0b	0.0
CONT I	0.6d	2.1	0.6c	2.1	0.0b	0.0

[1] Means followed by the same letter in the same column indicate no significant difference (P=0.05)

The following four grass species had higher cover values and were present in a wider range of treatment and amendment rates than all other grass species planted; Festuca arundinacea, Festuca ovina, Elymus trachycaulum, Poa compressa. Forb cover was low in all treatments with the exception of Trifolim repens. This species had significantly higher percent cover in Bozeman compost 1 and 0.5 rates incorporated, than in other treatments (Table 11).

Production

Bozeman compost applied at the 2.5 cm rate had significantly greater total production in September 1992 than any other treatment (Table 12). There was a general trend in the data with incorporated compost treatments yielding greater plant production than surface applied compost, fertilizer, and control plots.

The following four grass species had the highest production and were present in a wider range of treatment and amendment rates than all other grass species planted; Festuca arundinacea, Elymus trachycaulum, Poa compressa, Festuca ovina .Forb production was low for all species and in all treatments. Trifolium repens, however, had significantly greater production in plots treated with incorporated Bozeman compost at the 1 and 0.5 rates (Table 13). Two grass species present in the seed mix, Alopecurus pratensis and Deschampsia caespitosa, were not found growing on the plots. Bromus carinatus and the forb Astragalus cicer were identified growing in the plots, but in low numbers.

Table 11. Percent cover by species for different treatments in September, 1992 (N=15).

Treatment	Agri	Eltr	Agst	Alpr	Brca	Deca	Fear	Feov	Poco	Asci	Loco	Trre
EKO 1I	5.3	7.4	0.0	0.0	0.1	0.0	15.8	3.6	6.1	0.0	0.5	0.8
EKO .5I	2.2	2.6	4.9	0.0	0.2	0.0	6.7	6.1	3.0	0.0	2.8	0.0
EKO 1S	1.6	5.7	0.3	0.0	0.0	0.0	9.7	1.6	5.7	0.0	0.0	0.0
EKO .5S	0.6	3.6	1.6	0.0	0.3	0.0	5.7	5.2	1.2	0.0	0.8	0.0
BOZ 1I	0.1	2.1	0.2	0.0	0.0	0.0	17.1	0.6	0.8	0.0	0.7	28.1
BOZ .5I	0.1	2.8	0.7	0.0	0.0	0.0	8.9	1.1	1.6	0.5	0.0	9.7
MINECMB	0.0	0.9	5.8	0.0	0.7	0.0	5.0	3.6	4.1	0.0	0.0	0.1
FERT 1	0.0	3.4	0.9	0.0	0.0	0.0	0.1	2.9	0.6	0.0	0.0	0.0
FERT .5	0.0	1.4	0.3	0.0	0.3	0.0	2.7	5.3	1.3	0.0	0.3	0.0
CONT I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0
CONT II	0.0	0.0	0.1	0.0	0.0	0.0	0.1	3.0	0.7	0.0	0.0	0.0
TOTAL	9.9	29.9	14.5	0.0	1.6	0.0	71.8	33.5	25.1	0.5	5.4	38.7

Table 12. Total plant production (kg/ha oven dried weight) collected in September 1992 (N=15).

Treatment	Plant Production kg/ha	± 1 S.D.
EKO 1I	534ab	2.6
BOZ 1/2I	391bc	3.9
EKO 1S	265bc	2.7
EKO 1/2I	251bc	2.2
MINECMB	173c	2.0
EKO 1/2S	150c	1.4
FERT 1/2	75c	0.8
FERT 1	67c	1.3
CONT II	9c	0.2
CONT I	3c	0.1

[1] Total plant production values followed by the same letter in the same column indicates no significant difference (P=0.05).

Table 13. Biomass production by species for different treatments in kg/ha.

TREATMENT	Agri	Eltr	Agst	Alpr	Brca	Deca	Fear	Feov	Poco	Asci	Loco	Trre
EKO 1I	95.6	116.1	0.0	0.0	0.0	0.0	251.9	8.5	60.3	0.0	22.3	1.2
EKO .5 I	19.6	30.7	66.3	0.0	0.0	0.0	78.1	22.7	22.3	0.0	11.0	0.0
EKO 1S	10.4	52.8	0.0	0.0	0.0	0.0	140.0	7.5	54.1	0.0	3.7	0.0
EKO .5 S	2.3	41.2	13.2	0.0	0.0	0.0	52.6	38.6	1.8	0.0	0.0	0.0
BOZ 1I	0.0	29.5	0.0	0.0	0.0	0.0	250.9	0.0	31.2	0.0	0.0	425.8
BOZ .5 I	0.0	54.7	4.4	0.0	0.0	0.0	147.8	2.9	10.5	0.0	0.0	167.1
MINECMBO	0.0	7.7	37.2	0.0	0.0	0.0	57.8	22.3	47.9	0.0	0.0	0.0
FERT 1	0.0	38.8	7.9	0.0	0.0	0.0	0.0	16.3	4.7	0.0	0.0	0.0
FERT .5	0.0	11.4	1.7	0.0	1.3	0.0	24.1	28.8	6.1	0.0	0.0	0.0
CONT I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0
CONT II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.7	0.0	0.0	0.0	0.0
TOTAL	127.9	382.9	130.7	0.0	1.3	0.0	1003.2	159.3	238.9	0.0	37.0	594.1

SUMMARY AND CONCLUSIONS

The EKO compost and Bozeman municipal lawn waste compost produced beneficial effects on plant density, cover, and production at a high elevation mine site. Plots treated with two heavy rates of commercial nitrogen fertilizer and plots receiving unamended top soil had significantly lower plant density, cover, and production. Incorporating the compost 10 cm into the surface horizon generally produced greater vegetative growth during the second season than surface applications. Penetrometer tests in July and August of 1992 indicated a general trend towards less soil crust formation with the addition of compost.

Total grass cover and production were significantly greater on plots amended with 2.5 cm of EKO compost and then incorporated into the soil surface. Forb cover and production were significantly higher on plots in which 2.5 cm of Bozeman compost were incorporated. Analysis of soil samples from the most vegetatively productive plots and an adjacent, unamended, topsoiled area indicated differences in pH, EC, nutrient content, organic matter levels, and soil texture. Differences in chemical and physical properties between the two composts and the salvaged topsoil utilized in this study may have contributed to the variation in grass and forb growth on the plots.

Festuca arundinacea, Elymus trachycaulum, Poa compressa, and Festuca ovina had the highest production and cover of all the grasses planted. They also were present in a wider range of treatment and amendment rates than all other grass species. Forb production and cover were low in all treatments with the exception of Trifolium repens, which had significant growth in plots amended with Bozeman compost.

Several plants of introduced weedy species not found on the mine site were observed growing on the study plots. These plants could have been transported to the site by several means, one of which was contaminated compost. The majority of weedy plants were found on plots amended with Bozeman compost. All amendments transported to high-elevation sites should be classified weed free to prevent introduction of weedy species.

Results from this field study suggest that composted municipal wastes enhance the establishment and growth of herbaceous cover on this disturbed high elevation site. The use of composted materials for reclamation is in its infancy. Further research is needed to understand how different types and rates of composted municipal wastes can be utilized as an ammendment in the successful reclamation of high-elevation disturbances.

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APPENDICES

APPENDIX A

ABBREVIATIONS

Table 14. Plant species abbreviations.

Scientific Name[1]	Abbreviation
Agropyron riparium Scribn. & Smith	AGRI
Elymus trachycaulum (Link) Gould	ELTR
Agrostis stolonifera L.	AGST
Alopecurus pratensis L.	ALPR
Bromus carinatus Hook. & Arn.	BRCA
Deschampsia caespitosa L.	DECA
Festuca arundinacea Schreb.	FEAR
Festuca ovina L.	FEOV
Poa compressa L.	POCO
Astragalus cicer L.	ASCI
Lotus corniculatus L.	LOCO
Trifolium repens L.	TRRE

[1] Rumely and Lavin 1991

APPENDIX B

PRECIPITATION

Table 15. Monthly precipitation data in cm from the Basin Creek Mine (1988-1992).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1988	3.2	3.5	8.9	8.5	2.7	1.7	1.5	0.0	7.9	0.0	6.0	0.0
1989	4.1	2.1	7.1	2.2	4.9	6.3	4.9	7.5	3.2	4.5	2.4	4.6
1990	3.5	2.2	4.2	5.4	8.1	5.8	2.9	8.3	0.9	6.1	8.2	2.8
1991	7.0	3.2	8.2	16.1	11.2	7.6	2.6	2.0	5.1	3.0	7.6	8.0
1992	4.3	1.9	4.9	6.2	4.0	16.5	5.3	2.6	2.3	10.9	4.7	3.7

APPENDIX C

DATA

Table 16. Analysis of variance for penetrometer readings.

Month	Source	DF	MS	F-value	P-value
July	Treatment	10	6.4	7.25	0.0001
July	Plot	2	1.6	1.85	0.0127
August	Treatment	10	1.5	9.96	0.0001
August	Plot	2	0.3	2.06	0.1535

Table 17. Analysis of variance for plant density.

Plant	Source	DF	MS	F-value	P-value
Grass	Treatment	10	243.7	22.08	0.0001
Grass	Plot	2	30.8	2.79	0.0855
Forb	Treatment	10	26.4	6.69	0.0001
Forb	Plot	2	0.2	0.04	0.9599

Table 18. Analysis of variance for cover in 1992.

Cover	Source	DF	MS	F-value	P-value
Total	Treatment	10	691.9	8.09	0.0001
Total	Plot	2	45.0	0.53	0.5985
Grass	Treatment	10	361.2	6.00	0.0003
Grass	Plot	2	34.1	0.57	0.5759
Forb	Treatment	10	248.0	6.35	0.0002
Forb	Plot	2	18.8	0.48	0.6249

Table 19. Analysis of variance for total plant production.

Production	Source	DF	MS	F-value	P-value
Total	Treatment	10	16.8	7.75	0.0001
Total	Plot	2	1.8	0.85	0.4417

Table 20. Analysis of variance for plant cover by species.

Species	Source	DF	MS	F-value	P-value
Agri	Treatment	10	8.18	3.52	0.0080
Agri	Plot	2	7.33	3.16	0.0643
Eltr	Treatment	10	15.79	4.14	0.0033
Eltr	Plot	2	1.11	0.29	0.7516
Agst	Treatment	10	12.49	1.40	0.2512
Agst	Plot	2	0.64	0.07	0.0937
Brca	Treatment	10	0.16	1.06	0.4370
Brca	Plot	2	0.12	0.81	0.4604
Fear	Treatment	10	107.45	5.48	0.0006
Fear	Plot	2	44.74	2.28	0.1280
Feov	Treatment	10	11.40	1.85	0.1162
Feov	Plot	2	3.07	0.05	0.6146
Poco	Treatment	10	13.75	1.90	0.1071
Poco	Plot	2	9.00	1.24	0.3103
Asci	Treatment	10	0.08	1.01	0.4681
Asci	Plot	2	0.09	1.11	0.3475
Loco	Treatment	10	2.54	1.05	0.4395
Loco	Plot	2	0.91	0.38	0.6915
Trre	Treatment	10	225.0	7.75	0.0001
Trre	Plot	2	26.34	0.91	0.4196

Table 21. Analysis of variance for plant production by species.

Species	Source	DF	MS	F-value	P-value
Agri	Treatment	10	0.24	3.23	0.0123
Agri	Plot	2	0.13	1.75	0.1989
Eltr	Treatment	10	0.33	2.42	0.0447
Eltr	Plot	2	0.08	0.63	0.5410
Agst	Treatment	10	0.13	0.92	0.5373
Agst	Plot	2	0.05	0.36	0.7002
Brca	Treatment	10	0.01	0.94	0.5207
Brca	Plot	2	0.01	0.32	0.7272
Fear	Treatment	10	2.67	6.11	0.0003
Fear	Plot	2	1.16	2.66	0.0945
Feov	Treatment	10	0.05	1.85	0.1158
Feov	Plot	2	0.03	1.03	0.3760
Poco	Treatment	10	0.16	1.98	0.0933
Poco	Plot	2	0.28	3.46	0.0512
Asci	Treatment	10	0.00	0.00	0.0000
Asci	Plot	2	0.00	0.00	0.0000
Loco	Treatment	10	0.02	3.07	0.0158
Loco	Plot	2	0.01	0.81	0.4570
Trre	Treatment	10	5.31	6.43	0.0002
Trre	Plot	2	0.68	0.82	0.4535

Table 22. Standard deviation for biomass production by species and treatments.

TREATMENT	Agri	Eltr	Agst	Alpr	Brca	Deca	Fear	Feov	Poco	Asci	Loco	Trre
EKO 1I	1.7	1.4	0.0	0.0	0.0	0.0	2.6	0.1	0.9	0.0	0.0	0.1
EKO .5 I	0.4	0.8	1.5	0.0	0.0	0.0	0.9	0.5	0.5	0.0	0.4	0.0
EKO 1S	0.2	0.9	0.0	0.0	0.0	0.0	2.9	0.2	0.7	0.0	0.0	0.0
EKO .5 S	0.1	0.5	0.3	0.0	0.0	0.0	1.3	0.6	0.1	0.0	0.0	0.0
BOZ 1I	0.0	0.7	0.0	0.0	0.0	0.0	2.1	0.0	0.9	0.0	0.3	5.0
BOZ .5 I	0.0	1.0	0.2	0.0	0.0	0.0	1.6	0.1	0.3	0.0	0.1	2.6
MINECMBO	0.0	0.2	0.7	0.0	0.0	0.0	0.9	0.3	0.7	0.0	0.0	0.0
FERT 1	0.0	1.3	0.3	0.0	0.0	0.0	0.0	0.4	0.5	0.0	0.0	0.0
FERT .5	0.0	0.4	0.1	0.0	0.1	0.0	0.6	0.5	0.2	0.0	0.0	0.0
CONT I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
CONT II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0

Table 23. Standard deviation for cover by species and treatments.

Treatment	Agri	Eltr	Agst	Alpr	Brca	Deca	Fear	Feov	Poco	Asci	Loco	Trre
EKO 1I	8.6	6.7	0.0	0.0	0.4	0.0	13.1	2.8	6.6	0.0	1.0	0.8
EKO .5I	3.0	4.4	8.3	0.0	0.8	0.0	9.6	9.0	3.2	0.0	6.7	0.0
EKO 1S	2.3	5.6	1.0	0.0	0.0	0.0	15.0	2.5	8.1	0.0	0.0	0.0
EKO .5S	1.7	2.2	2.9	0.0	0.9	0.0	7.0	5.7	1.7	0.0	1.6	0.0
BOZ 1I	0.5	3.4	0.6	0.0	0.0	0.0	12.1	1.3	2.1	0.0	2.6	29.2
BOZ .5I	0.3	3.7	1.8	0.0	0.0	0.0	9.6	2.1	2.3	0.4	2.6	14.3
MINECMB	0.0	1.6	10.2	0.0	1.3	0.0	8.4	4.3	4.6	0.0	1.4	0.1
FERT 1	0.0	8.9	2.2	0.0	0.0	0.0	0.3	4.6	2.1	0.0	0.0	0.0
FERT .5	0.0	3.9	1.3	0.0	1.0	0.0	4.8	5.5	2.4	0.0	0.0	0.0
CONT I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	0.0
CONT II	0.0	0.0	0.3	0.0	0.0	0.0	0.3	3.6	1.2	0.0	0.0	0.0

Table 24. Grass cover(%) in September 1992.

Plot	Frame				
	1	2	3	4	5
1	0.5	18.0	35.0	2.0	1.0
2	32.0	20.0	30.0	45.0	15.0
3	12.0	30.0	14.0	8.0	20.0
4	3.0	1.5	8.0	1.0	4.0
5	8.0	36.0	15.0	23.5	1.0
6	4.0	15.0	4.0	16.0	15.0
7	13.0	11.5	12.0	22.0	12.0
8	0.0	5.0	4.0	2.0	11.5
9	30.0	45.0	16.0	65.0	59.0
10	0.0	0.0	0.0	0.0	0.0
11	45.0	39.0	38.0	30.0	68.0
12	18.0	10.0	17.0	6.0	8.0
13	3.0	15.0	14.0	6.0	6.0
14	15.0	36.0	38.0	32.0	8.0
15	16.0	15.0	34.0	32.0	10.0
16	2.0	23.0	29.0	22.0	26.0
17	3.5	14.0	16.0	2.0	11.0
18	19.0	52.0	20.0	30.5	7.0
19	26.0	6.0	15.0	16.0	8.0
20	1.0	1.5	1.5	3.0	1.5
21	18.0	20.0	42.0	23.0	32.0
22	21.0	11.0	20.0	13.0	9.0
23	30.0	7.0	70.0	27.0	8.5
24	24.0	9.0	38.5	17.0	11.0
25	10.0	24.0	25.0	9.0	25.0
26	13.0	11.0	10.0	7.0	7.0
27	0.0	0.0	0.0	0.0	0.0
28	16.0	8.0	6.0	11.0	1.0
29	48.0	39.0	57.0	52.0	35.0
30	14.0	25.0	54.0	30.0	42.0
31	0.0	0.0	0.5	0.0	8.0
32	6.5	3.0	4.5	35.0	0.5
33	22.0	42.0	10.0	10.0	12.0

Table 25. Forb cover(%) in September 1992.

Plot	Frame 1	2	3	4	5
1	0.0	0.0	0.0	0.0	0.0
2	14.0	10.0	0.0	15.0	0.0
3	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0
7	0.0	7.0	25.0	42.0	3.0
8	0.0	0.0	0.0	0.0	0.0
9	0.0	4.0	25.0	0.0	10.0
10	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0
12	0.0	40.0	0.0	4.0	0.0
13	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	1.0	0.0	0.0
15	0.0	4.0	2.0	4.0	2.0
16	0.0	0.0	0.0	4.0	0.0
17	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0
19	10.0	40.0	76.0	44.0	25.0
20	0.0	0.0	0.0	0.0	0.0
21	2.0	10.0	2.0	0.0	7.0
22	0.0	0.0	0.0	0.0	4.0
23	0.0	0.0	2.0	6.0	2.0
24	20.0	25.0	4.0	0.0	0.5
25	0.0	0.0	0.0	0.0	0.0
26	0.5	1.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	1.0	0.0	0.0
30	0.0	0.0	0.0	2.0	0.0
31	0.0	0.0	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0	0.0
33	8.0	12.0	70.0	90.0	34.0

Table 26. Cover(%) by species for each frame.

Plot	frame	Species AGRI	ELTR	AGST	BRCA	FEOV	FEAR	POCO	TRRE	LOCO	ASCI	Total
1	1	0	0	0	0	0	0	0	0	0	0	0.0
1	2	0	0	2	0	4	12	0	0	0	0	18.0
1	3	0	2	1	0	4	32	0	0	0	0	35.0
1	4	0	0	0	0	0	2	0	0	0	0	2.0
1	5	0	0	0	0	0	1	0	0	0	0	1.0
2	1	0	0	0	0	0	32	0	14	4	0	50.0
2	2	0	0	0	0	0	20	0	10	0	0	30.0
2	3	0	0	0	0	0	30	0	0	0	0	30.0
2	4	0	0	0	0	2	35	8	15	0	0	60.0
2	5	0	0	0	0	3	10	2	0	0	0	15.0
3	1	0	0	0	0	4	8	2	0	0	0	12.0
3	2	0	7	0	3	20	0	0	0	0	0	30.0
3	3	0	4	0	0	0	10	0	0	0	0	14.0
3	4	0	0	0	2	2	4	0	0	0	0	8.0
3	5	0	4	0	0	12	4	0	0	0	0	20.0
4	1	0	0	0	0	2	1	0	0	0	0	3.0
4	2	0	0	0	0	0	0	0	0	0	0	0.0
4	3	0	0	0	0	8	0	0	0	0	0	8.0
4	4	0	0	0	0	1	0	0	0	0	0	1.0
4	5	0	0	0	0	4	0	0	0	0	0	4.0
5	1	8	0	0	0	0	0	0	0	0	0	8.0
5	2	3	3	0	0	0	30	0	0	0	0	36.0
5	3	0	15	0	0	0	0	0	0	0	0	15.0
5	4	0	12	0	0	1	10	0	0	0	0	23.0
5	5	0	0	0	0	0	1	0	0	0	0	1.0
6	1	0	0	0	0	2	2	0	0	0	0	4.0
6	2	0	0	0	0	15	0	0	0	0	0	15.0
6	3	0	0	0	0	0	4	0	0	0	0	4.0
6	4	0	0	0	0	4	12	0	0	0	0	16.0
6	5	0	0	0	0	1	14	0	0	0	0	15.0
7	1	0	8	0	0	0	5	0	0	0	0	13.0
7	2	0	1	7	0	2	0	1	0	0	0	18.0
7	3	0	5	0	0	0	7	0	25	0	0	37.0
7	4	0	7	0	0	0	15	0	32	10	0	64.0
7	5	0	10	0	0	1	0	1	0	3	0	15.0
8	1	0	0	0	0	0	0	0	0	0	0	0.0
8	2	0	5	0	0	0	0	0	0	0	0	5.0
8	3	0	4	0	0	0	0	0	0	0	0	4.0
8	4	0	2	0	0	0	0	0	0	0	0	2.0
8	5	0	0	0	0	10	1	0	0	0	0	11.0
9	1	8	0	10	0	0	12	0	0	0	0	30.0
9	2	0	8	30	0	4	0	3	0	4	0	49.0
9	3	0	0	8	0	4	0	4	0	25	0	41.0
9	4	3	0	5	0	12	35	10	0	0	0	65.0
9	5	7	15	15	0	12	0	10	0	10	0	69.0
10	1	0	0	0	0	0	0	0	0	0	0	0.0
10	2	0	0	0	0	0	0	0	0	0	0	0.0
10	3	0	0	0	0	0	0	0	0	0	0	0.0

Table 26. - Continued.

Plot	frame	AGRI	ELTR	AGST	BRCA	FEOV	FEAR	POCO	TRRE	LOCO	ASCI	Total
10	5	0	0	0	0	0	0	0	0	0	0	0.0
11	1	25	5	0	0	0	0	15	0	0	0	45.0
11	2	0	15	0	0	4	0	20	0	0	0	39.0
11	3	8	0	0	0	5	25	0	0	0	0	38.0
11	4	0	0	0	0	0	30	0	0	0	0	30.0
11	5	15	20	0	0	3	15	5	0	0	0	58.0
12	1	1	2	0	0	0	15	0	0	0	0	18.0
12	2	0	8	1	0	0	0	1	40	0	0	50.0
12	3	0	0	0	0	0	15	2	0	0	0	17.0
12	4	0	0	2	0	0	0	4	0	0	4	10.0
12	5	0	0	0	0	0	0	8	0	0	4	48.0
13	1	0	0	0	0	2	0	0	0	0	0	2.0
13	2	0	15	0	0	0	0	0	0	0	0	15.0
13	3	0	0	0	0	12	0	2	0	0	0	14.0
13	4	0	0	0	0	2	0	3	0	0	0	6.0
13	5	0	3	0	0	3	0	0	0	0	0	6.0
14	1	2	0	1	0	1	8	4	0	0	0	16.0
14	2	2	0	0	0	24	8	2	0	0	0	36.0
14	3	4	0	0	3	28	0	0	0	1	0	36.0
14	4	7	0	0	0	4	18	3	0	0	0	32.0
14	5	0	4	0	0	2	0	2	0	0	0	8.0
15	1	0	0	4	0	8	4	0	0	4	0	20.0
15	2	0	3	0	0	6	0	6	0	4	0	19.0
15	3	0	4	0	0	12	15	3	0	2	0	36.0
15	4	0	4	0	0	5	22	2	0	4	0	36.0
15	5	5	5	0	0	0	0	0	0	0	0	10.0
15	5	5	5	0	0	0	0	0	0	0	0	12.0
16	1	0	0	0	0	0	0	2	0	0	0	2.0
16	2	0	4	5	3	8	0	0	0	0	0	20.0
16	3	0	0	22	0	0	0	4	0	0	0	26.0
16	4	0	5	3	3	6	0	8	0	4	0	26.0
16	5	0	0	2	3	8	5	8	0	0	0	26.0
17	1	0	0	1	0	2	0	0	0	0	0	3.0
17	2	0	0	4	0	2	0	8	0	0	0	14.0
17	3	0	0	0	0	16	0	0	0	0	0	16.0
17	4	0	0	0	0	2	0	0	0	0	0	2.0
17	5	0	0	8	0	3	0	0	0	0	0	11.0
18	1	5	14	0	0	0	0	0	0	0	0	19.0
18	2	2	0	0	0	0	50	0	0	0	0	52.0
18	3	2	4	0	0	7	4	3	0	0	0	20.0
18	4	2	5	1	0	7	2	15	0	0	0	30.0
18	5	2	5	0	0	0	2	0	0	0	0	7.0
19	1	2	5	2	0	4	15	0	10	0	0	36.0
19	2	0	4	1	0	0	1	0	40	0	0	46.0
19	3	0	0	0	0	0	15	0	75	0	0	91.0
19	4	0	4	0	0	0	10	2	40	4	0	60.0
19	5	0	0	0	0	0	8	0	20	5	0	33.0
20	1	0	0	0	0	1	0	0	0	0	0	1.0
20	2	0	0	0	0	1	0	0	0	0	0	1.0
20	3	0	0	0	0	1	0	0	0	0	0	1.0

Table 26. - Continued.

Plot	frame	AGRI	ELTR	AGST	BRCA	FEOV	FEAR	POCO	TRRE	LOCO	ASCI	Total
20	4	0	0	0	0	0	0	1	0	0	0	1.0
20	5	0	0	0	0	0	0	0	0	0	0	1.0
21	1	0	8	0	0	7	3	0	0	2	0	20.0
21	2	0	15	0	0	0	5	0	8	0	0	28.0
21	3	20	4	0	0	4	4	10	0	2	0	44.0
21	4	0	5	0	0	2	8	8	0	0	0	23.0
21	5	12	5	0	0	0	12	3	4	3	0	39.0
22	1	0	3	0	0	18	0	0	0	0	0	21.0
22	2	0	0	5	0	4	0	2	0	0	0	11.0
22	3	0	0	0	4	8	0	8	0	0	0	20.0
22	4	0	0	0	0	5	8	0	0	0	0	13.0
22	5	0	0	0	0	4	0	5	0	0	0	13.0
23	1	0	0	15	0	0	5	10	0	0	0	30.0
23	2	0	0	0	0	5	2	0	0	0	0	7.0
23	3	0	0	35	2	15	8	10	0	2	0	72.0
23	4	0	2	2	0	3	8	12	2	4	0	33.0
23	5	0	0	0	0	1	0	8	0	0	0	8.0
24	1	0	0	0	0	8	12	4	20	0	0	44.0
24	2	0	0	0	0	2	4	0	25	0	0	31.0
24	3	0	0	0	0	1	35	3	4	0	0	42.0
24	4	0	0	0	0	2	15	0	0	0	0	17.0
24	5	0	1	0	0	1	10	0	0	1	0	13.0
25	1	0	2	5	0	1	1	0	0	0	0	10.0
25	2	0	4	0	0	1	18	1	0	0	0	24.0
25	3	0	5	8	0	8	0	2	0	0	0	23.0
25	4	0	4	0	0	0	2	3	0	0	0	9.0
25	5	0	7	8	0	4	5	1	0	0	0	25.0
26	1	0	0	3	0	1	8	1	0	1	0	13.0
26	2	0	3	0	0	0	5	1	0	1	0	10.0
26	3	0	2	0	0	0	6	1	0	0	0	9.0
26	4	0	0	1	0	0	0	4	0	0	0	5.0
26	5	0	7	0	0	0	0	0	0	0	0	7.0
27	1	0	0	0	0	0	0	0	0	0	0	0.0
27	2	0	0	0	0	0	0	0	0	0	0	0.0
27	3	0	0	0	0	0	0	0	0	0	0	0.0
27	4	0	0	0	0	0	0	0	0	0	0	0.0
27	5	0	0	0	0	0	0	0	0	0	0	0.0
28	1	0	0	1	0	12	0	3	0	0	0	16.0
28	2	0	0	0	0	5	0	2	0	0	0	7.0
28	3	0	0	0	0	3	0	2	0	0	0	5.0
28	4	0	0	0	0	7	0	3	0	0	0	10.0
28	5	0	0	0	0	0	0	0	0	0	0	0.0
29	1	0	2	0	0	4	40	2	0	0	0	48.0
29	2	0	5	0	0	5	25	4	0	0	0	39.0
29	3	0	3	0	1	8	30	15	0	1	0	58.0
29	4	0	4	0	0	8	30	10	0	0	0	52.0
29	5	0	20	0	1	4	10	0	0	0	0	35.0
30	1	0	2	0	0	2	0	10	0	0	0	14.0
30	2	0	7	0	0	0	0	18	0	0	0	25.0
30	3	0	15	4	0	0	20	5	0	0	0	54.0
30	4	0	0	0	0	3	2	25	0	0	0	30.0

Table 26. - Continued.

Plot	frame	AGRI	ELTR	AGST	BRCA	FEOV	FEAR	POCO	TRRE	LOCO	ASCI	Total
30	5	0	4	0	0	4	25	10	0	0	0	42.0
31	1	0	0	0	0	0	0	0	0	0	0	0.0
31	2	0	0	0	0	0	0	0	0	0	0	0.0
31	3	0	0	0	0	0	0	0	0	0	0	0.0
31	4	0	0	0	0	0	0	0	0	0	0	0.0
31	5	0	0	0	0	8	0	0	0	0	0	8.0
32	1	0	0	0	0	6	0	1	0	0	0	7.0
32	2	0	0	0	0	3	0	0	0	0	0	3.0
32	3	0	4	0	0	0	0	0	0	0	0	4.0
32	4	0	35	0	0	0	0	0	0	0	0	35.0
32	5	0	1	0	0	0	0	0	0	0	0	1.0
33	1	0	12	0	0	0	20	0	0	8	0	30.0
33	2	0	2	0	0	0	40	0	8	4	0	54.0
33	3	0	0	0	0	0	10	0	70	0	0	80.0
33	4	0	0	0	0	0	10	0	90	0	0	100.0
33	5	0	5	0	0	0	1	0	27	4	0	46.0

Table 27. Grass density.

Plot	Frame				
	1	2	3	4	5
1	29	31	94	42	4
2	42	24	13	46	18
3	14	9	15	16	12
4	5	17	18	14	9
5	25	3	32	18	9
6	3	3	1	0	10
7	18	16	13	17	12
8	14	4	0	3	0
9	12	16	23	8	4
10	1	8	1	6	6
11	24	44	44	14	9
12	16	24	18	32	10
13	5	2	5	2	3
14	22	22	60	32	30
15	12	34	30	28	13
16	20	52	37	24	11
17	1	4	5	5	2
18	21	34	32	44	6
19	29	42	38	36	5
20	5	5	6	4	9
21	22	19	20	42	1
22	3	5	6	2	5
23	33	48	62	40	18
24	24	39	49	35	3
25	18	34	42	39	15
26	34	27	25	18	8
27	5	2	0	6	8
28	5	7	10	12	6
29	34	24	55	20	16
30	24	25	38	32	32
31	3	2	6	2	3
32	1	3	1	0	1
33	16	17	52	38	16

Table 28. Forb density.

Plot	Frame				
	1	2	3	4	5
1	17	7	64	4	0
2	5	5	8	7	3
3	5	5	3	3	1
4	1	2	0	1	1
5	3	1	0	3	0
6	0	0	0	0	0
7	2	0	2	4	4
8	0	0	0	0	0
9	8	0	4	1	0
10	0	0	0	0	0
11	8	12	4	3	1
12	4	2	2	6	0
13	0	0	0	0	0
14	2	14	8	12	9
15	0	25	17	16	3
16	7	4	17	4	0
17	0	0	0	0	0
18	3	4	0	0	2
19	12	8	18	10	1
20	0	1	1	1	0
21	1	2	7	3	1
22	0	0	0	0	0
23	5	15	24	16	7
24	11	18	7	8	0
25	12	8	10	0	3
26	4	4	7	2	0
27	0	0	0	0	0
28	0	0	0	1	0
29	3	6	3	2	2
30	0	3	1	2	10
31	0	0	0	0	0
32	0	0	0	0	0
33	3	2	8	5	3

Table 29. Grass density along transect 2.

Plot	Frame 1	2	3	4	5
1	29	31	94	42	4
2	42	24	13	46	18
3	14	9	15	16	12
4	5	17	18	14	9
5	25	3	32	18	9
6	3	3	1	0	10
7	18	16	13	17	12
8	14	4	0	3	0
9	12	16	23	8	4
10	1	8	1	6	6
11	24	44	44	14	9
12	16	24	18	32	10
13	5	2	5	2	3
14	22	22	60	32	30
15	12	34	30	28	13
16	20	52	37	24	11
17	1	4	5	5	2
18	21	34	32	44	6
19	29	42	38	36	5
20	5	5	6	4	9
21	22	19	20	42	1
22	3	5	6	2	5
23	33	48	62	40	18
24	24	39	49	35	3
25	18	34	42	39	15
26	34	27	25	18	8
27	5	2	0	6	8
28	5	7	10	12	6
29	34	24	55	20	16
30	24	25	38	32	32
31	3	2	6	2	3
32	1	3	1	0	1
33	16	17	52	38	16

Table 30. Forb density along transect 2.

Plot	Frame 1	2	3	4	5
1	17	7	64	4	0
2	5	5	8	7	3
3	5	5	3	3	1
4	1	2	0	1	1
5	3	1	0	3	0
6	0	0	0	0	0
7	2	0	2	4	4
8	0	0	0	0	0
9	8	0	4	1	0
10	0	0	0	0	0
11	8	12	4	3	1
12	4	2	2	6	0
13	0	0	0	0	0
14	2	14	8	12	9
15	0	25	17	16	3
16	7	4	17	4	0
17	0	0	0	0	0
18	3	4	0	0	2
19	12	8	18	10	1
20	0	1	1	1	0
21	1	2	7	3	1
22	0	0	0	0	0
23	5	15	24	16	7
24	11	18	7	8	0
25	12	8	10	0	3
26	4	4	7	2	0
27	0	0	0	0	0
28	0	0	0	1	0
29	3	6	3	2	2
30	0	3	1	2	10
31	0	0	0	0	0
32	0	0	0	0	0
33	3	2	8	5	3

Table 31. Production by species.

Plot	Frame	Species										
		AGRI	ELTR	AGST	BRCA	FEOV	FEAR	POCO	TRRE	LOCO	ASCI	Unkn
1	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50
1	2	0.00	0.00	0.08	0.00	0.18	0.86	0.00	0.00	0.00	0.00	0.00
1	3	0.00	0.20	0.00	0.00	0.18	2.26	0.00	0.00	0.00	0.00	0.00
1	4	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
1	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1	0.00	0.00	0.00	0.00	0.00	3.32	0.00	1.05	0.72	0.00	0.00
2	2	0.00	0.00	0.00	0.00	0.00	2.91	0.00	0.93	0.00	0.00	0.00
2	3	0.00	0.00	0.00	0.00	0.00	3.84	0.00	0.00	0.00	0.00	0.00
2	4	0.00	0.00	0.00	0.00	0.00	4.05	1.68	2.13	0.00	0.00	0.00
2	5	0.00	0.00	0.00	0.00	0.00	1.10	0.00	0.00	0.00	0.00	0.00
3	1	0.00	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00
3	2	0.00	1.37	0.00	0.00	1.18	0.00	0.00	0.00	0.00	0.00	0.00
3	3	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00
3	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	5	0.00	1.04	0.00	0.00	2.20	0.00	0.00	0.00	0.00	0.00	0.00
4	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50
4	3	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00
4	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	1	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	2	0.00	0.00	0.00	0.00	0.00	8.21	0.00	0.00	0.00	0.00	0.00
5	3	0.00	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	4	0.00	1.10	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.00
5	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 31. -Continued.

Plot	Frame	AGRI	ELTR	AGST	BRCA	FEOV	FEAR	POCO	TRRE	LOCO	ASCI	Unkn
6	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	2	0.00	0.00	0.00	0.00	1.25	0.00	0.00	0.00	0.00	0.00	0.00
6	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	4	0.00	0.00	0.00	0.00	0.00	2.20	0.00	0.00	0.00	0.00	0.00
6	5	0.00	0.00	0.00	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.00
7	1	0.00	1.51	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00
7	2	0.00	0.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	3	0.00	0.85	0.00	0.00	0.00	2.76	0.00	4.37	0.00	0.00	0.00
7	4	0.00	3.24	0.00	0.00	0.00	3.77	0.00	5.47	0.56	0.00	0.00
7	5	0.00	0.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	2	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	5	0.00	0.00	0.00	0.00	1.30	0.00	0.00	0.00	0.00	0.00	0.00
9	1	1.26	0.00	2.52	0.00	0.00	1.37	0.00	0.00	0.00	0.00	0.00
9	2	0.00	0.91	5.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	3	0.00	0.00	0.83	0.00	0.00	0.00	0.00	0.00	1.45	0.00	0.00
9	4	0.00	0.00	0.00	0.00	0.22	2.60	0.70	0.00	0.00	0.00	0.00
9	5	0.62	3.28	1.17	0.00	0.34	0.00	1.53	0.00	0.20	0.00	0.00
10	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	1	5.40	0.75	0.00	0.00	0.00	0.00	1.39	0.00	0.00	0.00	0.00

Table 31. - Continued.

Plot	Frame	AGRI	ELTR	AGST	BRCA	FEOV	FEAR	POCO	TRRE	LOCO	ASCI	Unkn
11	2	0.00	2.50	0.00	0.00	0.00	0.00	1.65	0.00	0.00	0.00	0.00
11	3	1.30	0.00	0.00	0.00	0.30	5.60	0.00	0.00	0.00	0.00	0.00
11	4	0.00	0.00	0.00	0.00	0.00	8.11	0.00	0.00	0.00	0.00	0.00
11	5	2.44	5.31	0.00	0.00	0.00	3.53	0.00	0.00	0.00	0.00	10.00
12	1	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00	0.00	0.00
12	2	0.00	1.84	0.00	0.00	0.00	0.00	0.00	7.38	0.00	0.00	0.00
12	3	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.00
12	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	5	0.00	0.00	0.00	0.00	0.00	0.00	1.20	0.00	0.00	0.00	0.00
13	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
13	2	0.00	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
13	3	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.00	0.00	0.00
13	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	1	0.00	0.00	0.00	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00
14	2	0.00	0.00	0.00	0.00	1.91	1.48	0.00	0.00	0.00	0.00	0.00
14	3	0.00	0.00	0.00	0.00	0.93	0.00	0.00	0.00	0.00	0.00	3.00
14	4	1.08	0.00	0.00	0.00	0.00	1.76	0.00	0.00	0.00	0.00	0.00
14	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	1	0.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00
15	2	0.00	0.00	0.00	0.00	0.49	0.00	0.32	0.00	0.00	0.00	0.00
15	3	0.00	0.00	0.00	0.00	0.99	1.00	0.00	0.00	0.00	0.00	0.00
15	4	0.00	0.00	0.00	0.00	0.33	4.75	0.00	0.00	0.00	0.00	0.00
15	5	0.21	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
15	5	0.21	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
16	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 31. - Continued.

Plot	Frame	AGRI	ELTR	AGST	BRCA	FEOV	FEAR	POCO	TRRE	LOCO	ASCI	Unkn
16	2	0.00	0.00	0.55	0.00	0.55	0.00	0.00	0.00	0.00	0.00	3.00
16	3	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00
16	4	0.00	0.95	0.00	0.00	0.68	0.00	0.95	0.00	0.00	0.00	0.00
16	5	0.00	0.00	0.00	0.00	0.50	0.67	0.81	0.00	0.00	0.00	0.00
17	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	2	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.00	0.00
17	3	0.00	0.00	0.00	0.00	0.91	0.00	0.00	0.00	0.00	0.00	0.00
17	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	5	0.00	0.00	1.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	1	1.07	3.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	2	0.00	0.00	0.00	0.00	0.00	8.73	0.00	0.00	0.00	0.00	0.00
18	3	0.00	0.00	0.00	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.00
18	4	0.00	0.21	0.00	0.00	0.52	0.00	1.48	0.00	0.00	0.00	0.00
18	5	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	1	0.00	1.05	0.00	0.00	0.00	3.46	0.00	1.01	0.00	0.00	0.00
19	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.42	0.00	0.00	0.00
19	3	0.00	0.00	0.00	0.00	0.00	3.24	0.00	12.98	0.00	0.00	
19	4	0.00	0.00	0.00	0.00	0.00	1.45	0.00	5.02	0.00	0.00	0.00
19	5	0.00	0.00	0.00	0.00	0.00	0.35	0.00	4.80	0.85	0.00	0.00
20	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
20	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
21	1	0.00	0.74	0.00	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00
21	2	0.00	1.62	0.00	0.00	0.00	0.66	0.00	0.18	0.00	0.00	2.00

Table 31. - Continued.

Plot	Frame	AGRI	ELTR	AGST	BRCA	FEOV	FEAR	POCO	TRRE	LOCO	ASCI	Unkn
21	3	4.11	0.00	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.00
21	4	0.00	0.70	0.00	0.00	0.00	1.45	0.77	0.00	0.00	0.00	0.00
21	5	1.09	1.04	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00	0.00
22	1	0.00	0.11	0.00	0.00	1.72	0.00	0.00	0.00	0.00	0.00	0.00
22	2	0.00	0.00	0.25	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00
22	3	0.00	0.00	0.00	0.19	0.47	0.00	0.73	0.00	0.00	0.00	0.00
22	4	0.00	0.00	0.00	0.00	0.05	0.34	0.00	0.00	0.00	0.00	0.00
22	5	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00
23	1	0.00	0.00	1.28	0.00	0.00	0.85	1.30	0.00	0.00	0.00	0.00
23	2	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00
23	3	0.00	0.00	2.34	0.00	1.05	2.75	1.61	0.00	0.00	0.00	0.00
23	4	0.00	0.00	0.00	0.00	0.00	1.22	1.83	0.00	0.00	0.00	0.00
23	5	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.00	2.00
24	1	0.00	0.00	0.00	0.00	0.44	1.06	0.37	2.67	0.00	0.00	0.00
24	2	0.00	0.00	0.00	0.00	0.00	0.52	0.00	5.18	0.00	0.00	3.00
24	3	0.00	0.00	0.00	0.00	0.00	3.98	0.00	0.00	0.00	0.00	0.00
24	4	0.00	0.00	0.00	0.00	0.00	6.56	0.00	0.00	0.00	0.00	0.00
24	5	0.00	0.00	0.00	0.00	0.00	1.65	0.00	0.00	0.00	0.00	0.00
25	1	0.00	0.00	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	2	0.00	0.56	0.00	0.00	0.00	2.15	0.00	0.00	0.00	0.00	0.00
25	3	0.00	0.56	0.88	0.00	0.45	0.00	0.00	0.00	0.00	0.00	2.00
25	4	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	5	0.00	0.64	0.87	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00
26	1	0.00	0.00	0.00	0.00	0.00	2.18	0.00	0.00	0.00	0.00	0.00
26	2	0.00	0.00	0.00	0.00	0.00	0.79	0.00	0.00	0.00	0.00	2.00
26	3	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.00	0.00	1.00

Table 31. - Continued.

Plot	Frame	AGRI	ELTR	AGST	BRCA	FEOV	FEAR	POCO	TRRE	LOCO	ASCI	Unkn
26	4	0.00	0.00	0.00	0.00	0.00	0.00	1.12	0.00	0.00	0.00	2.00
26	5	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	1	0.00	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00
28	2	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	1.00
28	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
28	4	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00	1.00
28	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
29	1	0.00	0.00	0.00	0.00	0.00	7.07	0.00	0.00	0.00	0.00	0.00
29	2	0.00	1.21	0.00	0.00	0.00	3.25	0.84	0.00	0.00	0.00	0.00
29	3	0.00	0.00	0.00	0.00	0.34	2.48	3.05	0.00	0.00	0.00	0.00
29	4	0.00	0.80	0.00	0.00	0.31	3.28	0.83	0.00	0.00	0.00	0.00
29	5	0.00	2.74	0.00	0.00	0.00	1.40	0.00	0.00	0.00	0.00	0.00
30	1	0.00	0.00	0.00	0.00	0.00	0.00	1.22	0.00	0.00	0.00	0.00
30	2	0.00	0.41	0.00	0.00	0.00	0.00	1.48	0.00	0.00	0.00	0.00
30	3	0.00	2.03	0.00	0.00	0.00	1.48	0.66	0.00	0.00	0.00	0.00
30	4	0.00	0.00	0.00	0.00	0.00	0.00	2.14	0.00	0.00	0.00	2.00
30	5	0.00	0.00	0.00	0.00	0.00	2.21	1.14	0.00	0.00	0.00	2.00
31	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
31	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 31. - Continued.

Plot	Frame	AGRI	ELTR	AGST	BRCA	FEOV	FEAR	POCO	TRRE	LOCO	ASCI	Unkn
31	5	0.00	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00
32	1	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00
32	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	3	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
32	4	0.00	4.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	1	0.00	2.32	0.00	0.00	0.00	2.23	0.00	0.00	0.88	0.00	0.00
33	2	0.00	0.00	0.00	0.00	0.00	7.93	0.00	1.01	0.50	0.00	0.00
33	3	0.00	0.00	0.00	0.00	0.00	0.42	0.00		12.20	0.00	0.00
33	4	0.00	0.00	0.00	0.00	0.00	3.33	0.00		14.52	0.00	0.00
33	5	0.00	1.05	0.00	0.00	0.00	0.00	3.00	2.80	0.40	0.00	3.00

Table 32. Penetrometer July 1992.

Plot	Random location number									
	1	2	3	4	5	6	7	8	9	10
1	3.75	1.75	3.25	2.75	4.50	2.50	3.75	3.75	2.75	4.50
2	2.25	4.00	2.25	2.25	1.75	2.50	2.75	1.75	2.25	2.25
3	2.50	4.50	4.50	1.75	4.75	1.75	4.00	2.75	4.00	3.75
4	2.50	4.50	4.25	4.00	1.75	4.50	4.50	4.50	4.50	3.50
5	1.50	4.50	1.75	2.00	1.75	1.75	1.75	2.00	1.25	2.00
6	2.50	1.25	4.50	3.00	1.75	1.50	1.75	4.50	1.75	1.50
7	4.00	4.50	2.50	1.50	2.50	2.00	2.75	2.75	2.25	4.50
8	2.25	1.50	4.50	1.75	2.25	2.50	1.75	1.75	4.50	3.00
9	2.50	3.00	1.50	2.25	2.25	3.25	2.75	2.25	2.25	3.00
10	5.01	0.50	4.25	1.50	2.50	1.50	1.75	2.25	4.50	1.50
11	2.50	1.75	1.50	2.00	3.75	1.75	2.00	2.00	1.50	2.25
12	3.25	2.00	1.50	2.50	3.00	3.25	2.50	2.25	2.00	4.25
13	2.75	4.50	3.00	2.75	1.75	2.75	4.50	2.75	4.50	2.00
14	2.50	4.50	4.50	2.75	2.25	2.50	2.75	3.50	4.25	3.25
15	2.25	1.75	3.75	4.50	2.50	4.50	2.50	3.00	3.25	4.50
16	4.50	3.00	3.25	3.25	2.75	4.25	2.25	4.50	2.00	3.00
17	2.75	3.75	4.50	4.50	4.50	2.00	2.50	2.75	4.50	3.50
18	2.25	2.25	1.75	2.00	2.50	2.50	3.50	2.00	2.00	2.00
19	3.50	4.50	3.25	2.50	4.50	2.50	4.50	3.00	2.75	4.50
20	1.75	2.75	4.50	4.25	2.50	2.75	4.50	4.50	4.50	4.50
21	1.75	2.50	1.50	2.00	2.25	2.25	2.00	2.00	1.75	1.75
22	2.00	4.50	1.50	2.75	3.50	3.75	3.50	2.00	4.50	1.50
23	4.00	4.50	4.50	4.25	1.50	4.50	4.00	4.50	4.50	4.50
24	2.50	3.50	4.50	3.00	3.00	2.00	2.75	3.75	4.50	2.50
25	3.75	2.00	4.50	2.00	4.50	4.50	2.25	4.50	2.50	4.25
26	2.75	3.50	3.25	2.50	1.75	3.00	2.25	2.75	2.75	4.50
27	3.25	1.75	2.50	4.00	4.50	4.50	3.75	4.50	4.00	2.50
28	4.50	4.25	1.75	3.50	2.50	4.50	3.50	4.50	4.50	3.25
29	3.25	3.00	1.00	1.75	3.00	4.00	2.00	2.75	2.50	4.50
30	2.00	1.50	4.00	2.00	2.50	2.50	2.25	2.25	1.25	4.00
31	4.00	2.00	2.00	3.00	2.00	2.50	1.75	3.50	2.50	4.50
32	4.50	3.25	2.00	4.50	2.50	2.50	1.75	4.50	3.00	2.25
33	3.75	2.50	2.25	4.00	4.50	4.00	4.50	1.50	3.50	2.50

Table 33. Penetrometer August 1992.

Plot	Random location number									
	1	2	3	4	5	6	7	8	9	10
1	3.75	1.75	3.25	2.75	4.50	2.50	3.75	3.75	2.75	4.50
2	2.25	4.00	2.25	2.25	1.75	2.50	2.75	1.75	2.25	2.25
3	2.50	4.50	4.50	1.75	4.75	1.75	4.00	2.75	4.00	3.75
4	2.50	4.50	4.25	4.00	1.75	4.50	4.50	4.50	4.50	3.50
5	1.50	4.50	1.75	2.00	1.75	1.75	1.75	2.00	1.25	2.00
6	2.50	1.25	4.50	3.00	1.75	1.50	1.75	4.50	1.75	1.50
7	4.00	4.50	2.50	1.50	2.50	2.00	2.75	2.75	2.25	4.50
8	2.25	1.50	4.50	1.75	2.25	2.50	1.75	1.75	4.50	3.00
9	2.50	3.00	1.50	2.25	2.25	3.25	2.75	2.25	2.25	3.00
10	5.01	0.50	4.25	1.50	2.50	1.50	1.75	2.25	4.50	1.50
11	2.50	1.75	1.50	2.00	3.75	1.75	2.00	2.00	1.50	2.25
12	3.25	2.00	1.50	2.50	3.00	3.25	2.50	2.25	2.00	4.25
13	2.75	4.50	3.00	2.75	1.75	2.75	4.50	2.75	4.50	2.00
14	2.50	4.50	4.50	2.75	2.25	2.50	2.75	3.50	4.25	3.25
15	2.25	1.75	3.75	4.50	2.50	4.50	2.50	3.00	3.25	4.50
16	4.50	3.00	3.25	3.25	2.75	4.25	2.25	4.50	2.00	3.00
17	2.75	3.75	4.50	4.50	4.50	2.00	2.50	2.75	4.50	3.50
18	2.25	2.25	1.75	2.00	2.50	2.50	3.50	2.00	2.00	2.00
19	3.50	4.50	3.25	2.50	4.50	2.50	4.50	3.00	2.75	4.50
20	1.75	2.75	4.50	4.25	2.50	2.75	4.50	4.50	4.50	4.50
21	1.75	2.50	1.50	2.00	2.25	2.25	2.00	2.00	1.75	1.75
22	2.00	4.50	1.50	2.75	3.50	3.75	3.50	2.00	4.50	1.50
23	4.00	4.50	4.50	4.25	1.50	4.50	4.00	4.50	4.50	4.50
24	2.50	3.50	4.50	3.00	3.00	2.00	2.75	3.75	4.50	2.50
25	3.75	2.00	4.50	2.00	4.50	4.50	2.25	4.50	2.50	4.25
26	2.75	3.50	3.25	2.50	1.75	3.00	2.25	2.75	2.75	4.50
27	3.25	1.75	2.50	4.00	4.50	4.50	3.75	4.50	4.00	2.50
28	4.50	4.25	1.75	3.50	2.50	4.50	3.50	4.50	4.50	3.25
29	3.25	3.00	1.00	1.75	3.00	4.00	2.00	2.75	2.50	4.50
30	2.00	1.50	4.00	2.00	2.50	2.50	2.25	2.25	1.25	4.00
31	4.00	2.00	2.00	3.00	2.00	2.50	1.75	3.50	2.50	4.50
32	4.50	3.25	2.00	4.50	2.50	2.50	1.75	4.50	3.00	2.25
33	3.75	2.50	2.25	4.00	4.50	4.00	4.50	1.50	3.50	2.50