Extensive portions of the desert grassland of southern Arizona, New Mexico and southwestern Texas have been invaded by woody species. Mesquite, creosote bush, cacti of the genus Opuntia, burroweed and snakeweed are among the principal invaders. The prime factors commonly believed to have caused this change are reviewed and evaluated. These are (1) change of climate, (2) grazing by domestic livestock, (3) plant competition, (4) rodents, (5) fire. Of these various factors, change of climate seems to have had the least effect. Fires that were formerly frequent and widespread were the chief agency restricting shrub invasion. Since fires have been controlled, the introduction of domestic livestock, plant competition and rodents have been effective agents that have favored woody plants at the expense of grasses. Had fires continued to sweep the grasslands down through the years to the present with their original frequency, the desert grassland would probably occupy about the same area today as it did prior to the white settlement of the Southwest.

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VEGETATION CHANGES IN SOUTHERN NEW MEXICO DURING THE PAST HUNDRED YEARS

JOHN C. YORK
and
WILLIAM A. DICK-PEDDIE
Department of Biology
New Mexico State University
Las Cruces, New Mexico, U. S. A.
phased...the great reduction in grass cover and speed with which the reduction has occurred. Much of the study area grass has been completely faced, and usually by two dominants—mesquite, creosotebush. Other shrubs or trees have also reached on areas previously in grass. Also, some still have grass on them.

The Bingham Area and the Shinnery Area (Fig. 1) used to compare other shrub cover, past and sent, and also to demonstrate that the changes not always meant the complete disappearance grass. Figure 4 shows the advance juniper and shrub (Artemesia filifolia Torr.) since the very. The blank area (G) is still covered by grass, s condition was also found in the Nett Area included in a figure). These areas have subseuently been found to have been lightly stocked the past 100 years.

His evidence of grass still occupying sites after years supports the evidence of Linney and cia (11) and of Martin (12), which indicates slight, if any, climatic change has taken place he past 100 years. The fact that grazing pressure been less where grass remains than in areas re it has virtually disappeared is strong indication that grazing is the factor responsible for the ease in desert shrubs.

The juniper areas (J) at the time of the survey largely restricted to foothills. Since that time have moved down and occupied the flats. The brush (S) was restricted to a small sandy area has moved out in a rather strange pattern. Some now occupies an ecotone between the juniper grass. Further investigation will be necessary at an explanation of this sagebrush ecol. The Bingham Area has more rainfall than her south and juniper appears to have replaced sotobush as the “invader” from the foothills. te Shinnery Area is detailed in Figure 5. This is unique to the state and provides an example shrub-tree, shin oak (Quercus havardii Rydb.), acing grass. This shrub oak type extends into as where you find its best expression. The re- ly occupied areas to the north appear to be an inion out of river valleys. The cap-rock (oloic formation) has understandably prevented expansion of the shinnery belt to the east; how- the rather modest expansion to the west is ling. The shinnery appears to be growing on same sandy sites as the mesquite which bounds belt on the west (Fig. 5, M). More information sorsary before we can propose an explanation for the portion of the shinnery belt which has apparently been held in check in its westward expansion.

**SUMMARY AND CONCLUSIONS**

The mesas of southern New Mexico were covered by grass in the middle of the last century. This grass was primarily gram grass (Bouteloua sp.).

Mesquite occurred in limited areas on shallow sandy soil, but more importantly it occurred around Indian campsites. Creosotebush was restricted to well-drained gravelly hilltops and narrow patches in the foothills of mountains. Juniper stands were on mountain foothills usually higher or further north than creosotebush. The area was correctly classified desert grassland.

All the other species have greatly expanded their ranges during the past hundred years, usually in response to a reduction in grass cover. The grass has not completely disappeared or even changed its boundaries in all cases. In one instance a secondary replacement of mesquite by creosotebush has taken place. The speed of the recent occupation by mesquite may be attributed to the effects of cattle in the presence of ideal source pockets of mesquite around old Indian campsites.

The speed with which this almost complete replacement of grass has taken place in southern New Mexico coupled with the fact that isolated areas are unchanged indicates that climate has not been a factor. The topography and biomass potential of southern New Mexico make it highly unlikely that the area could ever have carried a fire. The appearance of the grazing industry is the only factor which coincides with the time of this spectacular change.

Although the grasslands of southern New Mexico were extensive and dominated the area, they were on the xeric edge of the continental Grassland Formation. A single factor such as grazing was evidently enough to set in motion a series of relatively rapid events which culminated in a desert shrub vegetation.

Even though the climate is virtually unchanged, the surface horizon which 100 years ago supported grassland is undoubtedly long gone down the arroyos or formed into dunes. Until there is a climatic change, therefore, most of southern New Mexico can be considered to be a desert climax rather than a desert grassland climax as it was 100 years ago.
Higher plants use nitrogen mainly in the form of nitrate ion, NO₃. They cannot use atmospheric nitrogen. They absorb nitrate from the soil. However, nitrate does not occur in appreciable amounts in rock minerals, but is produced in the soil from atmospheric nitrogen through the action of bacteria.

Two types of bacteria can change gaseous nitrogen (N₂) to amino form (NH₂) and incorporate it into protein in their bodies. One type lives in nodules on the roots of a host plant—such as legume. The other type lives free in the soil independent of a host. Both types fix mineral nitrogen in organic matter.

When nitrogen-fixing bacteria die, the protein nitrogen in their bodies is converted to ammonia (NH₃) by other bacteria. Ammonia is then changed first to nitrite ion (NO₂⁻) and then to nitrate ion (NO₃⁻) by still other kinds of bacteria. Thus, nitrogen is converted to a form usable by the plant. The energy used by bacteria for this conversion is derived mainly from carbohydrates in plant roots. Maximum food is provided bacteria when the roots are laden with food reserves.

Soil fertility, therefore, is maintained or increased by growing a maximum cover of vigorous plants on the land. Maximum production of plants is a prime objective of multiple-use rangeland management. Perennials—especially such fibrous-rooted ones as grasses—are superior to annuals for building and maintaining soil fertility because of their larger and deeper penetrating root systems.

**HOW PLANT COMPOSITION CHANGES**

The species composition of the vegetation changes continuously. It changes slowly in natural succession but may change rapidly under the influence of destructive forces such as grazing or fire.

In natural succession one association of plants after another, from low to high forms, grows on a site as the soil develops to maturity. Fundamentally, one association of plants succeeds or replaces another because the soil changes. Changes in vegetation, therefore, occur either as soil develops or as it is degraded through erosion.

Rate of natural succession is correlated with rate of soil development and so is slow. One association of plants may not succeed another for hundreds, if not thousands, of years.

The plant association that establishes on the mature soil is called the climax association. It is the most stable and long-lived plant group because the soil is stabilized. The tendency in natural plant succession is for development of the climax association.

The plant composition may be changed relatively quickly in a matter of only a few years by improper grazing. Initial changes in composition result from selective grazing of plants by animals. Further changes may then occur because of soil erosion.
The tendency is for tap-rooted plants to become established on eroded sites. Such plants can grow on very young soils—even solid rock—and erosion makes a soil younger. On millions of acres of grassland sites where soil had developed to the point of supporting fibrous-rooted and rhizomatous plants, the rangeland is now dominated by tap-rooted plants because of soil erosion induced by grazing and other destructive forces. Some such plants are: sagebrush, rabbit brush, snakeweed, creosote bush, mesquite, juniper, and pinyon pine. In general, these plants are less desirable for grazing and other uses than the plants they replaced.

The composition of the vegetation on a given site is controlled mainly by the condition of the soil. Rate of improvement of the composition is determined by the degree of soil degradation and by the competition between existing and invading plants for occupancy of the site. Even under ideal management of grazing, improvement of the range will be slow where the soil has been eroded appreciably.

**PLANT GROWTH**

The seasonal growth and development of perennial plants is illustrated here with Idaho fescue (fig. 1). The growth pattern of this bunchgrass applies to other grasses and similar plants and to forbs and woody plants as well. Shoot growth of herbaceous plants and twig growth of woody plants are comparable. Plant growth stage is best expressed in terms of percentage growth and greenness of the shoot.

The elapsed time from start of growth to dormancy in Idaho fescue is 6 or 7 months. Shoot growth is completed in about 4 months. The plant loses greenness over a comparable period. The moisture content of the plant starts declining about the time the plant is half grown and starts slowing in growth. The total weight of the shoot declines late in the season because seeds shatter and plant parts dry out and disintegrate.

(The period of growth and development of different species on different sites may differ appreciably from that for this species. Some plants dry completely or shed leaves as they become dormant.)

Roots start growth before the shoot. Root growth is largely completed by the time the shoot is half grown. By then the plant is growing most rapidly and presumably has greatest need for a fully developed root system.

Approximately one third of the roots die each year. They start to die about the time root growth ends. A large amount of organic matter gets into the soil each year this way.

**REGROWTH**

Potential for the plant to regrow during the season is highest early in the season, and declines with advance of the season as soil moisture and the growth impetus of the plant decline (table 3). After the plant is half grown and starts slowing in growth rate, its regrowth is negligible. Grasses may
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Improvement of vegetation depends on promoting conditions that will allow the vegetation to develop toward climax. The prime condition is to remove or properly regulate the cause of deterioration. Clements (10) put it this way:

"From the very nature of climax and succession, development is immediately resumed when the disturbing cause ceases, and in this fact lies the basic principle of all restoration or rehabilitation. Left undisturbed, every bare, seral or denuded area begins its slow but inevitable movement to the climax wherever the latter has not been destroyed over too large a territory to permit the mobilization of successive populations."

This principle is the foundation of good grazing and resource management.
Wildlife changes:

As vegetation changes accompany soil changes, so wildlife changes accompany vegetation changes, both as vegetation trends toward climax condition and as it deteriorates. In many instances wildlife habitat has been improved with site deterioration and encroachment of tap rooted plants on sites. Sagebrush has improved sage grouse habitat, and bitterbrush and other shrubs deer habitat. Herbaceous weeds have improved habitat for rabbits and rodents which in turn improved habitat for raptors. With site improvement, the habitat may become less favorable for others. Such changes can be expected and must be accepted because man can do no less than promote the best possible soil condition. Where site deterioration has been heavy the changes will occur slowly.
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EDWARD J. KORMONDY is Provost and Professor of Biology at the University of Southern Maine in Portland. His many books include Introduction to Genetics, Concepts of Ecology, and General Biology: The Integrity and Natural History of Organisms.

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The popular image of a desert as a barren wasteland of sand is a misleading one. Even the most desolate and arid region is a Biotic Ecosystem of plant and animal life. People have always lived in deserts and traveled across them. Desert lands, and the forces which produce them, are highly significant influences on worldwide climate and ecology.

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GORDON L. BENDER is Professor of Zoology at Arizona State University in Tempe. He specializes in studying the ecology of desert insects.


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Soil is the basic land resource and must be protected at all costs. Soil is renewable and will regenerate if destroyed, but this process may take hundreds if not thousands of years. Land productivity depends on soil fertility. On rangelands, fertility is lost mainly through erosion. It is maintained by keeping a maximum protective cover of vegetation and organic litter on the soil.

Soil may be defined as a thin decomposing layer on the surface of the earth containing mineral matter, organic matter, air and water in proportions suitable for plant growth. It is formed mainly under the influence of climate and vegetation and has special characteristics.

FORMATION

The mineral matter in the earth's crust is broken down progressively to smaller particles and ultimately to molecules and ions, in which forms it is usable by the plant. Weathering forces, such as temperature, water and wind, gravity and chemical interactions, decompose the minerals. Low forms of plant and animal life, such as bacteria, algae, fungi, and protozoa, grow in the soil as soon as mineral decomposition begins. Later higher forms grow -- plants with large root systems and such animals as insects, worms, and rodents ultimately become abundant.

Plants and animals play important roles in soil formation. When these organism die and decompose, humus is formed in the soil. Humus is a residue of organic matter decomposition. It consists of relatively decay-resistant materials, such as lignin, waxes, fats and microbial cells. It is nearly black and darkens the soil.
Soil Formation

As soil forms, it tends to differentiate into two horizontal layers: the A or upper horizon and the B or lower horizon. These two horizons differ in color and in physical and chemical properties. Horizon A tends to be darker because of greater concentration of humus. Most humus is derived from plant roots which are concentrated in the upper portion of the soil. Horizon A also tends to become loamy. Some of the finer mineral particles in the upper portion of the soil are carried down to lower depths by water and deposited and so horizon B tends to be clayey.

The effects of weather and plant and animal influences decrease as depth below the ground surface increases. Any effect is ultimately neutralized. Hence soil forms only to a certain depth. It rests on the parent mineral matter which may be solid rock or fine material such as sand or silt.

A soil with well developed horizons may take several thousand years to form. A soil is said to be young while the horizons are developing and mature or old when the horizons are well defined. In arid regions the horizons may not become clearly evident because of limited rainfall and vegetation and high oxidation rate of organic matter.

If destroyed by erosion, a soil will re-form because conditions for soil formation are ever present. In a sense, a soil is made younger by erosion. Thus, a soil may be viewed as a living mass capable of regeneration.
FERTILITY

The fertility of a soil is determined by the availability of mineral elements and water to the plant and such factors as aeration, and degree of acidity or alkalinity of the soil.

Twelve chemical elements known to be essential for plant growth are obtained from the soil. Those used in greatest amounts by the plant are nitrogen, phosphorus, potassium, sulfur, calcium, and magnesium. Those used in lesser amounts are iron, zinc, copper, manganese, boron, and molybdenum. Most soils contain adequate amounts of these elements -- except possibly nitrogen -- for normal plant growth. Most of these nutrients, however, are bound up in relatively insoluble mineral compounds, in living plant and animal tissues, and in the colloidal fraction of the soil. Therefore, they are not immediately available to the plant. Only nutrients in the soil solution in molecule and ion form are immediately available.

Organic Matter

The availability of minerals and other soil characteristics that influence soil fertility are governed largely by soil organic matter. When plant and animals die and decompose, a large supply of nutrients is released into the soil in a form readily used by the plant. Organic matter increases the moisture-holding capacity of the soil and therefore the amount of nutrients that can be held in solution and made available to the plant. Several different acids are generated in the soil as a result of respiration and decomposition of organic matter; the most important is carbonic acid. These acids speed the solution of nutrients
from mineral matter and also promote the availability of nutrients held on colloidal particles in the soil.

Colloidal particles are of two types: mineral and organic. The mineral colloids are essentially small bits of clay, and organic colloids small bits of humus. These particles are negatively charged and attract and hold positively charged ions including hydrogen ion. Hydrogen ion has a strong tendency to displace other ions and to put them into the soil solution. Important nutrients, such as calcium and magnesium, are relatively easily displaced.

Organic colloids are formed more rapidly and are much more dynamic in storing and making nutrients available to the plant than mineral colloids. The affinity of colloidal particles for hydrogen and other positively charged ions tends to reduce active acidity and alkalinity of the soil solution to a narrow range. Organic matter promotes a granular soil structure and increases water percolation and soil aeration. It lightens a heavy soil and binds a light one.

**Nitrogen**

Nitrogen, used in large amounts by the plant, is readily leached from the soil. It is more likely to become deficient than any other mineral nutrient.

Higher plants use nitrogen mainly in the form of nitrate ion, \( \text{NO}_3^- \). They cannot use atmospheric nitrogen. They absorb nitrate from the soil. However, nitrate does not occur in appreciable amounts in rock minerals, but is produced in the soil from atmospheric nitrogen through the action of bacteria.
Two types of bacteria can change gaseous nitrogen ($N_2$) to amino form ($NH_2$) and incorporate it into protein in their bodies. One type lives in nodules on the roots of a host plant -- such as legume. The other type lives free in the soil independent of a host. Both types fix mineral nitrogen in organic matter.

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