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Ecological Factors Influencing Plant Distribution in the Shadscale Zone of Southeastern Utah

Kamal M. Ibrahim
Utah State University

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ECOLOGICAL FACTORS INFLUENCING PLANT DISTRIBUTION IN THE SHADSCALE ZONE OF SOUTHEASTERN UTAH

by
oustafa
Kamal M. Ibrahim

A dissertation submitted in partial fulfillment
of the requirements for the degree

of

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in

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INTRODUCTION

The intimate relationship between vegetation and soil has long been a subject of interest. Ecologists, soil surveyors, and ranchers have recognized that vegetation differences are often accompanied by variation in soil types.

Early studies on this relationship were subjective. Too often data were not sufficiently complete to allow accurate appraisal of the interrelationships. In recent years, however, comprehensive studies have been conducted and quantitative data on plants and edaphic factors have been gathered and analyzed statistically. However, in vast portions of the arid zones of the world knowledge is either lacking or contradictory in nature. The importance of the arid zone to world welfare is such that tremendous effort to understand the functioning of the desert ecosystem is justified.

A relatively little known arid area is the western extension of the Colorado Plateau Province into eastern Utah. The lower elevations of this region support a sparse vegetation consisting of several species of the genus Atriplex. Those species form relatively simple sometimes nearly pure communities.

The study reported herein was confined to the shadscale zone in which Atriplex confertifolia provides the matrix of the climax vegetation. Embedded in this matrix are various edaphic or topo-edaphic communities that have developed under one macro-climate.

The objectives of this study were:

1. To classify and identify the different plant communities which occur in the shadscale zone.

2. To investigate and evaluate the relationships between vegetation characteristics and edaphic factors in each plant community.

3. To isolate ecological factors that may contribute to plant distribution.

4. To develop vegetation soil guides which could minimize soil survey problems throughout *Atriplex* landscapes of southeastern Utah.

5. To study the geological factors that contributed to the origin of the different parent material.

REVIEW OF LITERATURE

The concept of using individual species or plant communities as indicators of soil and climate is of long standing. Hilgard (1906) summarized fifty years work and pointed the way toward a scientific study of the chemical constituents of soil in relation to the distribution of native vegetation.

Chamberlin (1878) in his geological survey of Wisconsin was the first to recognize that plant communities were better indicators than individual species. He classified vegetation into communities with more or less definite indicator value.

Shantz (1911) contributed to the development of the concept of plant indicators, especially in regards to recognition of land capabilities. Clements (1920) provided a comprehensive treatise covering the entire field of plant indicators and discussed in considerable detail the use of plants to denote climatic and edaphic conditions.

Sampson (1939, p. 156) in a review of the concept stated:

> The plant indicator concept is based on a cause-effect relationship, where the effect is taken as a sign of the cause. All plants are admittedly a measure of their environment. Because plant production, and to some extent, form of growth, is determined by the habitat, any plant species may to some extent, indicate the nature of its surroundings; yet only a few key species of a given locality are, as a rule, sufficiently restricted by growth conditions to be helpful.

The existence and successful reproduction of a plant species are limited by the ranges of intensity of the different habitat factors. Mason (1946) mentions that climatic, edaphic or biotic factors, singly or in various combinations, serve to restrict the range of some plant species. He also stated that environment permits the functioning of those individuals whose tolerances have been preadapted to certain conditions that prevail in that environment. He further added that edaphic factors are most likely to occur in sharply distinct patterns and often within small areas.

Mason (1954) mentions that the inbreeding population, through the mechanism of gene exchange, sets up a self-perpetuation system, as a result of which functioning individuals are continually being produced as old ones die.

Merriam (1898) made the first major attempt to use climatic data to interpret the distribution of North American species.

Good (1931) stated that plant distribution is primarily controlled by the distribution of climatic factors and secondarily by the distribution of edaphic factors. Shantz and Piemeisel (1940) pointed out that the southern and northern desert shrub types of the Great Basin indicate major climatic differences but the sub-types within each indicate local differences in soil chemical or physical properties.

In the Unita Basin of Utah and Colorado, Graham (1937) considered that altitudinal life zones were primarily the result of climatic factors. Edaphic and physiographic differences within these zones resulted in the different vegetation types.

Gardener and Retzer (1949) showed that climate is the primary factor in determining the type of vegetation. Within a climatic zone, soils exert the strongest effects on plant distribution.

Hubbard (1950) working in southeastern Saskatchewan, indicated that changes within a vegetation zone are generally influenced by latitude, elevation and longitude. He stated that vegetation, if properly interpreted, could answer many questions regarding soil and climatic conditions.

Billings (1952) stated that vegetation and soil are subject to the control of climate which has a leading role in the development and maintenance of both.

Nikiforoff (1942) raised the question of change in climate with time and mentioned that "the steady state" of a mature soil depends on the maintenance of climate stability.

In the southern interior of British Columbia, Spillsbury and Tisdale (1944) found that within a certain vegetation zone, the depth of soil profile was the most important edaphic characteristic with respect to species dominance.

Because of its role in water relations, texture of soil becomes increasingly important as precipitation becomes less. Hardy (1945) found this to be particularly true in southwestern Utah.

Both plant distribution and production have been related to soil fertility (Millar, 1955). Soil reaction has been known to be a major factor through its effect on the availability of different nutrient ions. Young (1934) showed some correlation between pH values and vegetation distribution in his study of soil heterogenity in the Adirondack Mountains, New York.

In southern Arizona Martin and Fletcher (1943) noted remarkable similarities between the vertical zonation of soils on Mt. Graham and the great soil groups. They reported that with increased elevation, the volume weights and pH decreased while water holding capacity increased.

Marks (1950) studying soil and vegetation relationships in the lower Colorado Desert of Arizona, found significant relationship between vegetation and salt content as well as moisture holding capacity, but not between vegetation and pH values.

Weislander and Storie (1952) reported that a combined soil and vegetation classification would help in the evaluation of range sites as a basis for range improvement and development. In their approach, broad kinds of vegetation cover were determined and the soil series was taken as a mapping unit.

Olson (1952) pointed out that the examination of soil profile is especially important in an area where one general range type dominates several kinds of soils, each of which may have a different potential. He added that two soil profiles alike in all details are capable of producing the same kind and density of plants. He also mentioned that unlike profiles rarely have the same productiveness.

In South Texas, narrow transition zones between four distinct plant communities lead Box (1959) to investigate local edaphic conditions as factors in vegetational distribution. He found that soil physical characteristics were significantly different between the various communities and that for purposes of characterizing different soils they were more important than soil chemical characteristics.

Most investigators who have worked in the shadscale zone have concluded that shadscale vegetation is usually indicative of soil that is to some extent saline below the first foot (Aldous and Shantz, 1924; Weaver and Clements, 1938; Kearney et al., 1914; Stewart et al., 1940; and Shantz and Piemeisel, 1940). Billings (1945) found that this is also true in some but not all the shadscale areas.

Kearney et al. (1914) found that sagebrush (Artemisia tridentata) occurred chiefly on bench lands on coarse-textured soils with low salt content. They found that greasewood (Sarcobatus vermiculatus) occupied soils with a fairly high moisture equivalent and a high salt content from the second foot down.

In the Escalante Valley, Utah, Shantz and Piemeisel (1940) found that sagebrush occurred on moderately light-textured soils with low salt content, whereas shadscale occupied areas that had a high salt content and either hard-pan or coarse gravel at 18 to 24 inches, and greasewood occupied heavier-textured and more saline soils.

Billings (1945) and Fautin (1946) have questioned the universality of the association of shadscale and subsoil salinity. In eastern Nevada, Billings (1949) found that the shadscale is not always a reliable indicator to salinity in subsoil.

In the Escalante Desert, Fireman and Hayward (1952) made a quantitative study of several indicator species occurring in mixed and pure associations to determine the relation of the physical and chemical characteristics of soils to vigor, age and distribution of indicator plants. The pH values of saturated soil paste and 1:10 soil-water suspensions, particularly of the surface soil, were generally lower under sagebrush and the adjacent bare areas than under shadscale and greasewood. The soluble salt content was appreciably higher under shadscale and greasewood than under other shrubs or adjacent bare soil.

In the Unita Basin, Graham (1937) studied sagebrush and shadscale communities in particular and noted that sagebrush grew where moisture was greater and where soils were more permeable and relatively saline free.

In western Utah, Stewart et al. (1940) found that shadscale occurred on light-textured soils with salt content varying from 0.02 to 0.05 percent depending on the depth of sampling.

Gates et al. (1956) conducted a very comprehensive study of the following associations: sagebrush, shadscale, winterfat (*Eurotia lanata*), saltbush (*Atriplex nuttallii* var. *nuttallii*) and greasewood. They found significant differences between these vegetation types in regard to the following soil chemical and physical characteristics: total soluble salts, conductivity of a saturation extract, one-third atmosphere moisture percentage, exchangeable sodium and soluble sodium. The classification of habitats was primarily based upon the abundance of a single species.

Roberts (1950) investigated the chemical effects of salt tolerant shrubs on soils in arid and semi-arid regions of southwestern Utah. The soils under greasewood had a higher pH value than those under shadscale and both values were higher than the pH values of bare soil. Similar relationships were found with respect to exchangeable sodium and electrical conductivity of a soil saturation extract.

Billings (1949) found in western Nevada that where shadscale occupies deep sands, the sands were water-deposited as lake sediments, alluvial fans, or bajadas but are probably not of an aeolian origin. In western Utah, Kearney et al. (1914) and Shantz and Piemeisel (1940) found that shadscale associations principally occur on the heavier soils of the playas. It was also reported by Stewart et al. (1940) that preferred habitats of shadscale in western Utah were playas with high moisture content.

Shadscale soils may have prominent hardpans (Shantz and Piemeisel, 1940). Billings (1949) reported that in many shadscale areas in the western parts of the Great Basin, a distinct calcareous hardpan 10 to 15 centimeters in thickness occurred from 10 to 20 centimeters below soil surface. In general, this pan layer was not very strongly cemented and did not appear to impede the growth of roots to any extent. He also mentioned that qualitative tests for the presence of carbonates in soil profiles showed that under shadscale, carbonates occurred mainly in the pan layer but that they could be present throughout the entire soil profile. He also mentioned that the depth of the carbonate layer under sagebrush was between 60 and 80 centimeters from the soil surface. He considered that the relatively greater depth of the pan layer in the sagebrush zone was evidence of an earlier moist climate.

DESCRIPTION OF THE AREA

Location

The study area lies in the mid portion of the rolling lands that extend from the southeastward-facing escarpment of the Book Cliffs to the Colorado River. Located on the west side of Cisco Wash, Grand County, Utah (Figure 1), the study area includes approximately 13.5 square miles. U. S. Highway 50 and 6 form the north boundary. Sagers Wash marks the southwestern limits.

Topography and Elevation

To the north, the topography rises gradually to the Book Cliffs with pediment remnants rising above the general level. These pediment remnants are intersected and shaped by drainages which may be taken as the main factor in the development of the present configuration of the landscape. The Mancos shale areas are characterized by rolling undulating relief which may be attributed to recent gullying and badland development. The elevation on the high level of pediment remnant is 4,492 feet above mean sea level. The low flat land near Sagers Wash lies at an elevation of 4,183 feet.

History

The history of land use and management of the study area is not well known. However, it seems that the area was at one time heavily grazed by sheep. Campbell (1922, p. 197) wrote:

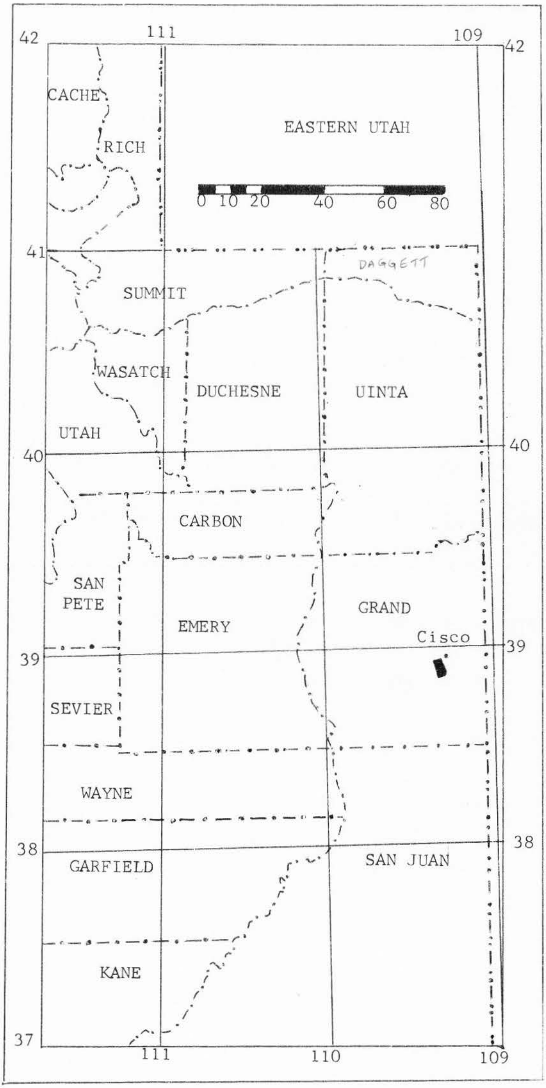

Figure 1. Location of the study area.

> . . . The village of Cisco which is one of the largest shearing and shipping points in this great sheep country. One unfamiliar with this region might think that there was little or no pasturage here for even a sheep, but when rain falls the country is green with grass and even in times of drought there are forage plants that might not be noticed by the accustomed eye.

It can be hypothesized from Beckwith's report (1855, p. 61) that there has been little change in the severe soil erosion and the sparse vegetative cover which existed over one hundred years ago and which continue to prevail today. Of a location near the upper forks of Cisco Wash, Beckwith wrote:

> September 28, . . . Deep, narrow gullies cut in the clay and soil, with perpendicular sides, obstructed our progress more than usual today, as they were from four to sixteen feet deep, and from one to twelve feet wide. September 29, . . . A neighboring ravine furnished a limited supply of grass, but for once, sage was even more scarce than grass, the country being entirely destitute of wood, and presenting only a picture of aridity and bareness.

The area is lightly grazed by sheep and cattle during the winter time.

Climate

Precipitation

The study area is located in the low land south of the Book Cliffs. The United States Weather Bureau records (1953-1962) for Cisco, Utah have been summarized in Table 1.

The region has a semi-arid climate, with a mean annual rainfall of 6.15 inches. The monthly means for a nine year period reveal that summer is a period of low precipitation. Except for December, winter, spring and fall precipitation is fairly constant. Rainfall for the most part accompanies thunderstorms. However, there is a tendency for rainfall to increase from mid July through early fall.

Table 1. Temperature and precipitation data for Cisco, Utah, 1953-1962.

Climatic factors	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Average temperature (°F)	24.3	27.9	35.6	51.7	55.4	64.2	79.5	76.7	66.6	53.2	36.0	26.8	
Average minimum temperature (°F)	10.5	18.3	24.5	34.0	44.5	52.2	60.4	58.2	47.8	35.2	20.7	13.0	
Average maximum temperature (°F)	38.1	44.3	55.9	69.3	80.6	92.9	98.5	95.2	85.4	70.8	51.6	39.6	
Precipitation inches	0.71	0.76	0.63	0.53	0.57	0.18	0.23	0.10	0.69	0.80	0.62	0.33	6.15

Temperature

There is a wide daily and annual variation in temperature. During the summer, the days are usually hot, but the nights usually get cool. The temperature rises abruptly at sunrise and falls off with an equal rapidity at sunset. During the winter there is a similar wide daily range in temperature. January and February are the coldest months.

Geology

Southeastern Utah lies within the Colorado Plateau Province which in general is characterized by an arid climate, high altitude, bare rock surface, and an intricate system of cliff-walled canyons that have been dissected into high tablelands of horizontal or slightly inclined sedimentary strata along major streams and many smaller tributaries (McKnight, 1940).

These general features of the province as a whole are developed in the area treated in this study.

Stratigraphy

The lithologic characteristics, and succession and relation of exposed formations are summarized in Table 2 for convenient reference and direct comparison.

Upper cretaceous

The Mancos shale is a thick formation consisting largely of steel-gray well bedded marine shale and subordinated beds of gray limestone and argillaceous sandstone (Dane, 1935). Veinlets of gypsum in the form of scattered selenite plates occur on weathered surfaces (Gregory, 1938 and McKnight, 1940). The Ferron sandstone, a member of

Table 2[a]. General section of rock formation and outcropping in the study area.

System	Series	Formation	Characters of rocks
Quarternary	Pleistocene (?)		Remnants of pediments representing three periods of erosions. The gravels range from boulders of sandstone to sand or fine gravel. The coarser material occurs on the highest pediment remnants.
		Unconformity	
Cretaceous	Upper-cretaceous	Mancos shale	Lead-gray marine shale.
			Buff thin-bedded sandstone and sandy shale (Ferron).
			Lead-gray marine fossiliforous shale.

[a] Modified from Clark (1928) and Dane (1935).

the lower part of the Mancos shale formation, outcrops in the southeastern part of the study area.

Quaternary deposits

The greater part of the surface of the Mancos shale was at more than one time coated with sheets of gravel and sand spread by torrential streams that drained and eroded the adjoining uplands of the Book Cliffs (Clark, 1928).

Three sets of low mesas or benches (Figure 2) capped with gravel are obviously erosion remnants of old extensive pediments that formerly sloped gradually from the cliffs to the low flat lands. These pediment remnants are found at three levels, but those at the intermediate level seem to be better preserved than those at other levels (Fisher, 1936). These remnants were reported at similar areas by Baker, 1946; Clark, 1928; Gilluly, 1929; McKnight, 1940; and Spiecker, 1931.

The abandonment and trenching of these pediments may be the result, in part, to stream diversions (Rich, 1935) or climatic changes (Darton, 1920 and Rich, 1935). While the older pediments existed, streams could not cut deeper into them and the land was reduced to a gentle slope. Later the streams acquired greater cutting power and succeeded in trenching and eroding the old pediment except where it was protected on the divides (Darton, 1920).

The three distinct levels of the pediment remnants indicate the different epi-cycles of erosion have occurred. The old pediment slopes were controlled by running water discharged from the Book Cliffs. The transport of debris upon the pediment slope was solely accomplished by

Figure 2. The three levels of pediment remnants are shown in the background. The community of _Atriplex corrugata_ appears in the foreground.

water work. The contrast in the size of the boulders on the first level of pediment remnant and gravel on both the second and third levels could be taken as an evidence that the different levels of the old pediments were controlled by different rates and/or amounts of run-off from the Book Cliffs (Williams, 1961).

It could be hypothesized that the climatic changes may be related to those that caused the different levels of Lake Bonneville.

Drainage

The study area is included within the boundaries of two separate drainages. Cisco Wash drains the eastern part of the area and Sagers Wash drains the western portion.

These streams are intermittent. In the spring and early summer they flow continuously as a result of melting snow from the Book Cliffs. In the summer the flow is partially dissipated by evaporation before it reaches the Colorado River. The extensive surface of bare soil, when subjected to local thunderstorms, favors maximum run-off particularly in the lower parts of their stream courses.

Vegetation

The study area is confined to the shadscale zone in southeastern Utah. As to physiognomy, the most notable feature of the vegetation is the prominance of different *Atriplex* species.

Shadscale forms the matrix of the climax vegetation. Embedded in this matrix are four vegetation types which are edaphically controlled climax communities. Narrow transitional zones occur between the four different communities.

The shadscale zone extends northward to the boundary of the sagebrush zone which occupies the foothills of the Book Cliffs at an elevation of 5000 feet above sea level.

Soil

The soils of the study area have characteristics of Sierozem zonal soils. No intensive soil survey work has been carried out in the immediate study area, thus the soils were totally unknown. Some soils belong to established series and others are classified as eroded phases of established series.

Parent materials for the soils studied were either of sedimentary origin (Mancos shale) or were alluvial outwash on the pediment remnants.

METHODS AND PROCEDURES

In general, most of the published literature indicates that there is no widely accepted method which will enable application of synecological investigations to land classification. This is due, in part, to the complex nature of these arid-desert ranges, and in part, to the difference in the training of ecologists.

Determination of Vegetational Characteristics

The preliminary survey based on abundance and prominence of species (Weaver and Clements, 1938) indicated that the vegetation of the study area could be classified into the four following different plant communities: (1) *Atriplex confertifolia-Hilaria jamesii* (shadscale-galleta grass), (2) *Atriplex nuttallii* var. *nuttallii-Hilaria jamesii* (saltbush-galleta grass), (3) *Atriplex nuttallii* var. *gardneri-Aster xylorrhiza* (saltsage-woody aster), and (4) *Atriplex corrugata* (mat saltbush).

This field investigation though qualitative in nature, was necessary in order that the vegetation might be classified into major categories. In order to verify the classification of these communities, quantitative data obtained from nine different locations for each community were subjected to a phytosociological analysis. However, the classification of vegetation into four different plant communities in terms of their floristic composition only without reference to the interrelationships of the ecological factors involved within and between the communities in an insensitive method. Therefore, soil data and vegetation characteristics were tested statistically to test the differences of ecological factors between and within the different communities.

Reconnaissance

After completion of the intensive vegetation and soil analysis within the area of study, a reconnaissance of approximately 200 square miles around the area was undertaken to investigate the occurrence of the different communities and their associated soils. The reconnaissance revealed that these habitat types could be recognized on the basis of vegetation and soil information obtained from the intensive survey of the study area.

Field method of determining vegetation characteristics

The 25-square foot method (Gobel et al., 1958; Green et al., 1951; and Sharp, 1949) was used to determine the following vegetation characteristics: number of plants per plot, canopy coverage and basal cover for each species as well as for the vegetation. The equipment consisted of a 25-square foot frame supported on telescoping legs. A sliding crosspiece, 1 x 5 foot subdivided into 1/16-square foot units was used for accurate readings. Each 1/16-square foot unit represents 0.25 percent of the 25-square foot frame.

This method utilized the basic concepts underlying the range reconnaissance and square-foot density range survey methods (Stewart and Hutchings, 1936). The plot size (5 x 5 foot) is large enough to include the different species yet small enough to be viewed readily from above.

For each plant community, a total of 15 different locations separated widely from one another were marked on an aerial photo. Nine out of the 15 locations for each community were selected at random for intensive study. Two transects (each 100 foot long) were run at random in each location. Ten plots (5 x 5 foot) were spaced uniformly on each transect.

A short training period was conducted prior to the estimation of both canopy and basal cover. Estimates of vegetation cover were checked further by estimating bare ground which when subtracted from 100 should equal the sum total cover for vegetation.

Phytosociological characteristics

Basal cover. Basal cover (basal area) refers to the extent of ground actually covered by stems at the soil surface (Hanson, 1950).

Estimations are made to the nearest 0.25 percent which represents the area of 1/16 of a square foot. For annuals and small-sized plants 1/4 of this area (1.5 x 1.5 inches) was used for precise estimates.

The basal cover of mat forming plants such as mat saltbush (*Atriplex corrugata*) or mosses was estimated as the total area from which these plants exclude the growth of other species. Perennials were considered as one plant if the individual stems are not further apart than 1.5 inches.

This method is not well adapted to sampling annual species because of their small basal area.

Canopy cover. Canopy cover (herbage cover) refers to the area of ground occupied by crown canopy as viewed from above (Hanson and Churchill, 1961). It is one of the most important characteristics of vegetation.

Density. Density refers to the number of individual plants per unit area (Becking, 1957). A square foot was taken as a unit area in this study. In this study, densities of cryptogams were not computed.

Floristic composition. A complete list of species has considerable value in characterizing the plant community. Each species has a definite range of tolerance for environmental conditions (Hanson and Churchill, 1961). A single species may be valuable in delimiting vegetation but when additional species are used the plants become of greater indicator value for characterization of the area they occupy. Both floristic composition and soil development are important means of describing the syndynamic stages for the different communities included in this study.

Frequency. Frequency expresses the percentage of sample plots in which a given species occurs (Curtis and McIntosh, 1950).

Constancy. Constancy refers to the percentage of occurrence of a species in stands (locations) that belong to the same community. It is a measure essentially the same as stand frequency (Hanson and Churchill, 1961).

In this study, the different species were classified into five classes of constancy according to Hanson and Churchill (1961) as follows:

Class	Percent constancy
1	Less than 20
2	21 to 40
3	41 to 60
4	61 to 80
5	81 to 100 .

A fairly high number of species in classes 4 and 5 indicates floristic homogeneity in a given community.

Fidelity. Fidelity is the degree to which species are restricted or confined to certain communities (Braun-Blanquet, 1932). In this study the vegetation was classified into different communities on the basis of fidelity, constancy and frequency.

The different fidelity classes that were used in this study follows:

(A) Characteristic species

- (5) Exclusives-plant species exclusively or almost exclusively restricted to a certain plant community. Exclusives usually exhibit high frequencies and constancies.
- (4) Selectives-plant species with strong preference for a specific plant community but also occurring in other communities, however, then it occurs sparingly, infrequently or rarely.
- (3) Preferents-plant species often occurring in other communities but with optimum definitely in one community.

(B) Companion species

- (2) Indifferents-plant species without any definite preference for a certain community.

(C) Accidental species

- (1) Strangers-plant species rare or accidental intruders from another plant community or relict species from a proceeding community. These species have low frequencies and constancies. They usually have their definite optimum outside the considered community.

Classes of fidelity are taken from Braun-Blanquet (1932) and Becking (1957) and slightly modified. In this study accidental species are restricted to those rare species having low frequencies and constancies in the considered community.

The name of each association is derived from the names of the species that have high fidelity, constancy and frequency.

Structure. Layering or stratification refers to the occurrence of organisms or their parts at more or less definite levels (Hanson and Churchill, 1961). It is largely due to the variations exhibited by differences in growth habits and their range of tolerances to environmental factors involved in a given habitat.

Soil Sampling

To differentiate between the different plant communities and to test the recurrence of each community at different locations, trenches were excavated (Figure 3) in the vicinity of the vegetation transects at each of the nine locations of the four plant communities. The trenches were 20 inches wide, 20 to 25 feet long and extended to the parent material thereby exposing the entire zone of root penetration. Each location was described as to relief, degree and direction of the slope, internal drainage, and elevation. Each soil profile was described in the field following the procedure outlined in the Soil Survey Manual (1951). The horizons in each profile were carefully described as to depth, thickness, dry and moist color, field texture, structure, hydrochloric acid effervescence, consistence, nature of boundary, and parent material.

A composite sample was obtained from each horizon. All samples were allowed to reach air dry moisture condition in a store-room. They were then sieved by hand using a 2 mm screen. Samples that appeared to have no appreciable amount of gravel and stones (5%) were poured through a mechanical crusher with about 4 mm opening.

Chemical and Physical Analyses of Soil Sampling

Each sample was subjected to a series of analyses for each physical and chemical characteristic which was thought to influence the distribution of a plant in saline soil. The physical analyses made on these samples were: particle size distribution, saturation moisture percentage and one-third atmosphere moisture percentage. The chemical analyses were: pH of saturated soil paste, pH of a 1:5 soil-water suspensions, total soluble salts, electrical conductivity of saturation extract, cation exchange capacity, percentage and amount of exchangeable sodium, amount of exchangeable potassium, and lime percentage.

Particle size distribution was determined by the Bouyoncos method (1936) except that sodium hexametaphosphate was used as the dispersing agent. The clay fraction was recorded in two ways--that less than 0.002 mm in diameter and that less than 0.005 mm in diameter.

Procedures used for the chemical and the remaining physical analyses are described by the U. S. Salinity Laboratory (1954). Methods used were as follows: for pH of saturated soil paste, method 21a; for pH of a 1:5 soil-water suspensions, method 21b; for total soluble salts, method 5; for electrical conductivity of saturation extract, method 4a; for cation exchange capacity, method 19; for amount and percentage of sodium, method 10a; for amount of exchangeable potassium, method 11a; for saturation moisture percentage, method 27a; for one-third atmosphere moisture percentage, method 31; and for lime percentage, method 23c. These analyses were made by the Soil Conservation Service Soil Laboratory that is located on the campus of Utah State University.

RESULTS AND DISCUSSIONS

The Plant Communities of the Shadscale Zone

The total number of species in the four different communities was rather limited. A summary of the different phytosociological characteristics is presented in Table 3 in which the communities are classified on the basis of fidelity, constancy and frequency of exclusive and selective (classes 5 and 4) species. Hypothetical profiles to illustrate horizon designations for soils dominated by the four plant communities are shown in Figure 4. The profile descriptions of these soils and the nomenclature of their horizons are shown in Appendixes 2 to 6.

The association of Atriplex confertifolia-Hilaria jamesii (Atripletum confertifolae)

On the basis of the different heights of the various life-forms, the vegetation is divided into three strata; the shrub, herbaceous and the moss layer. These strata rarely overlap except when soil moisture is abundant.

Figure 6 shows that 15 different species occur in this community with shrubs species being slightly more numerous than the other growth-forms. However, the variation between the number of different species within the various growth-forms is less in this association than in each of the other three communities.

Phytosociological characteristics. Table 3 shows that shadscale, galleta grass, Bromus tectorum (cheatgrass), and mosses were the

Table 3. Summary of the phytosociological synthetic factors[a] of the four plant communities of the shadscale zone of southeastern Utah.

Species	*Atriplex confertifolia*-*Hilaria jamesii*											*Atriplex nuttallii* var. *nuttallii*-*Hilaria jamesii*											*Atriplex nuttallii* var. *gardneri*-*Aster xylorrhiza*											*Atriplex corrugata*										
	Fidelity class	Constancy class	Frequency % in different locations									Fidelity class	Constancy class	Frequency % in different locations									Fidelity class	Constancy class	Frequency % in different locations									Fidelity class	Constancy class	Frequency % in different locations								
			1	2	3	4	5	6	7	8	9			1	2	3	4	5	6	7	8	9			1	2	3	4	5	6	7	8	9			1	2	3	4	5	6	7	8	9
Atriplex confertifolia	4	5	100	95	80	100	95	90	95	85	95		2							15	10	20																						
Atriplex nuttallii var. *nuttallii*	1	2	5				5					4	5	100	80	60	70	100	95	65	95	95	1	2			15		5		10													
Atriplex nuttallii var. *gardneri*																							5	5	100	100	100	100	100	100	100	100	100											
Atriplex corrugata												1	2		25		15			15			1	2				5	5	5				3	5	100	100	100	100	100	100	100	100	95
Gutierrezia sarothrae													1							20																								
Tetradymia glabrata													1								20																							
Artemisia spinescens	1	1					5					3	5	5	65	30		25	5	5	25	5	3	4		20	90	50	10		75	20	45	1	2		20							20
Eurotia lanata												3	3	5			5			65	15	20	1	2			45		5					1	2			5	15					
Eriogonum microthecum	1	1					5					3	2		5					25		10	3	2	15			40				20	25											
Opuntia polyacantha	4	5		5	35	10	15	30	15	35	25	1	2			5						5																						
Sclerocactus whipplei	1	1							5																																			
Aster xylorrhiza												2	3	60	25			5		15		10	3	5	80	80	70	80	100	75	100	100	80	2	4	20	50		5	30	25			55
Sphaeralcea grossulariaefolia	1	2				5	10					3	5	20	5	5	15	50		5	15	5	2	2	20		20	5						1	1				5					
Astragalus canadensis	1	1		5																																								
Hilaria jamesii	3	5	90	95	100	75	100	95	85	80	95	3	5	70	80	100	85	85	90	95	70	80	1	2	10				5															
Oryzopsis hymenoides	1	1						5				2	4	70	45			20		15	5	5	1	3			35		15		5	5		1	2	5								5
Salsola kali var. *kenuifolia*																																		1	1		10							
Eriogonum inflatum	2	2		5		15	35					2	3	60	10				5	5	30		2	5	65	70	40	15	95	5	15	10		2	4	75	50	30	45	15	5	5		
Malcolmia africana	2	3	45	10		15			5			1	2				5					20	1	1				5						1	2							15		15
Bromus tectorum	3	5	35	35	10	5	20	25	20	5		1	2						5		5		1	1			5							1	1									5
Plantago tweedyi																																		1	1					5				
Mosses	3	5	45	50	20	55	40	65	30	60	10	2	2			10				15	25													1	1	20								
Lichens	1	2				5			5	10		1	1							5																								

[a] Explanation of phytosociological characteristics is given on pages 23 to 25. No value for fidelity was given if the given species does not occur in a certain community.

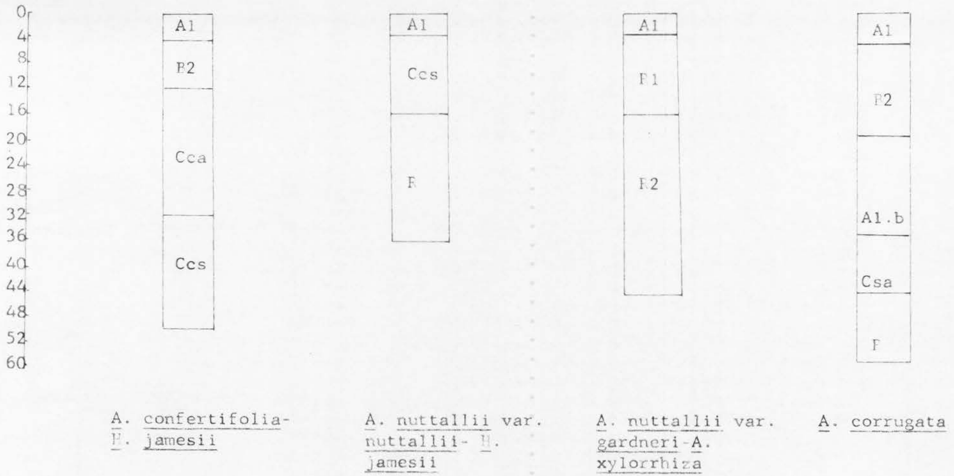

Figure 4. Hypothetical profiles to illustrate horizon designations and depth from ground surface under the different plant communities.

Figure 5. The association of *Atriplex confertifolia*-*Hilaria jamesii*.

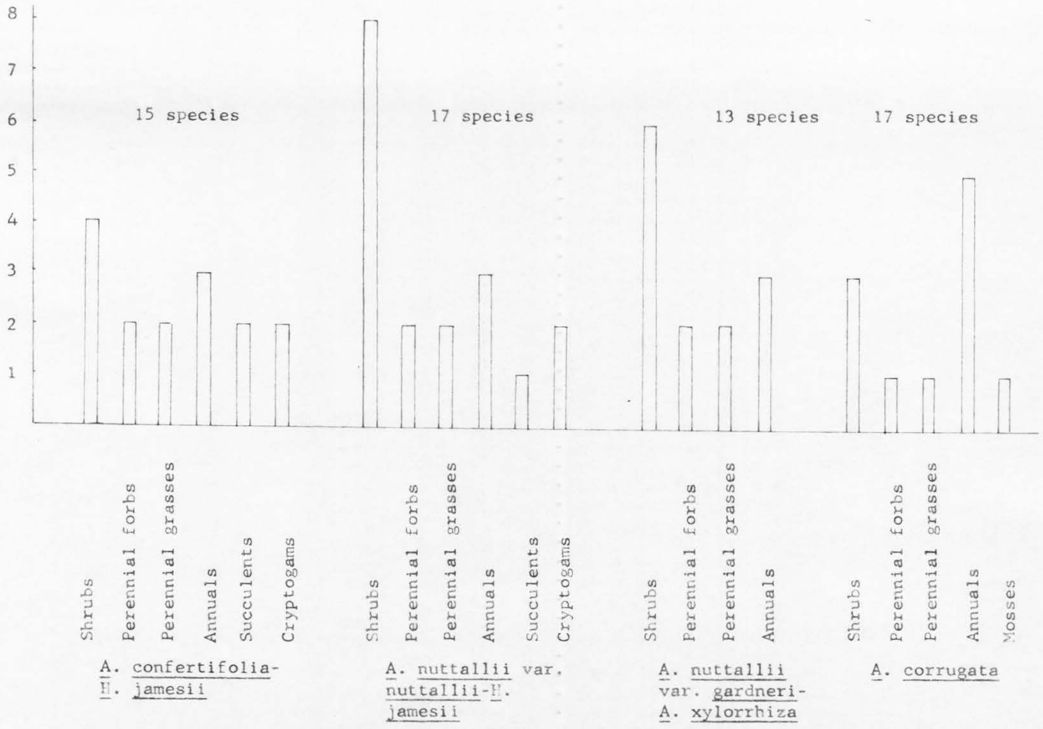

Figure 6. The number of species of the different growth habits in each of the four communities.

important species in this community. Shadscale has the highest frequency, constancy and fidelity. Galleta grass has equally high frequency and constancy but a lower fidelity than shadscale as a result of its occurrence in other communities. Both cheatgrass and mosses have a high constancy but lower frequency than the previous two species. Their fidelities are lower than the shadscale as a result of their occurrence in other communities.

Table 4 shows the mean values for density, canopy cover and basal cover for each species. The total canopy cover was 9.37 percent whereas the total basal cover averaged 6.08 percent.

Shadscale contributed 31.56 percent of the total basal cover and 48.65 percent of the total canopy cover.

Galleta grass composed 49.63 percent of the total basal cover and 35.49 percent of the total canopy cover. It also had the highest density value 1.05 for this association.

Shadscale and galleta grass composed 81.20 percent of the total basal cover and 84.14 percent of the total canopy cover.

Opuntia polyacantha (prickly pear) and mosses were the next abundant species. Prickly pear consisted 8.06 percent of the total basal cover and 5.37 percent of the total canopy cover. The mosses composed 8.24 percent of the total basal cover and 5.35 percent of the total canopy cover.

In general, the perennial herbs, annuals, succulents and cryptogams contributed lower values of density, basal cover, and canopy cover than perennial grasses and shrubby vegetation.

Relationships between vegetation characteristics. Table 5 shows a summary of simple correlation coefficients between the percent cover contributed by the two prominent species as well as the different

Table 4. Mean values of vegetation characteristics for nine locations of the association of *Atriplex-confertifolia-Hilaria jamesii*.

Species	Density[a] (no. of plants/ sq. ft.)	Total basal cover	% Composition of basal cover	Total canopy cover	% Composition of canopy cover
Atriplex confertifolia	0.0993	1.9189	31.5583	4.5567	48.6510
Atriplex nuttallii var. *nuttallii*	0.0009	0.0311	0.5115	0.0378	0.4036
Artemisia spinescens	0.0002	0.0003	0.0049	0.0011	0.0117
Eriogonum microthecum	0.0001	0.0003	0.0040	0.0011	0.0117
Total for shrubby plants	0.1015	1.9506	32.0796	4.5967	49.0780
Opuntia polyacantha	0.0084	0.4900	8.0585	0.5033	5.3736
Sclerocactus whipplei	0.0002	0.0011	0.0181	0.0011	0.0117
Total for succulents	0.0086	0.4911	8.0766	0.5044	5.3853
Sphaeralcea grossulariaefolia	0.0007	0.0011	0.0181	0.0044	0.0470
Astragalus canadensis	0.0011	0.0011	0.0181	0.0011	0.0117
Total for perennial forbs	0.0018	0.0022	0.0362	0.0055	0.0587
Hilaria jamesii	1.0451	3.0178	49.6308	3.3244	35.4939
Oryzopsis hymenoides	0.0002	0.0000	0.0000	0.0003	0.0032
Total for perennial grasses	1.0453	3.0178	49.6308	3.3247	35.4972
Eriogonum inflatum	0.0309	0.0311	0.5115	0.1022	1.0912
Malcolmia africana	0.0684	0.0384	0.6315	0.1378	1.4713
Bromus tectorum	0.0673	0.0456	0.7499	0.1911	2.0403
Total for annuals	0.1666	0.1151	1.8929	0.4311	4.6028
Mosses	0.0000	0.5011	8.2411	0.5011	5.3501
Lichens	0.0000	0.0026	0.0428	0.0026	0.0278
Total for cryptogams	0.0000	0.5037	8.2839	0.5037	5.3779
Total for association	1.3238	6.0805	100.0000	9.3661	99.9999

[a] Values do not represent actual measurements but result from computing fractional value from one plot of the nine stands sampled.

Table 5. Correlation coefficients between vegetation characteristics of the association of *Atriplex confertifolia-Hilaria jamesii*.

	% of shadscale in canopy cover	% of galleta grass in canopy cover	% of total shrubs in canopy cover	% of total succulents in canopy cover	% of total perennial forbs in canopy cover	% of total perennial grasses in canopy cover	% of total annuals in canopy cover
Percent of galleta grass in canopy cover	-.873**						
Percent of total shrubs in canopy cover	.998**	-.873**					
Percent of total succulents in canopy cover	.072	-.310	.041				
Percent of total perennial forbs in canopy cover	.125	-.292	.124	-.261			
Percent of total perennial grasses in canopy cover	-.873**	.999**	-.873**	-.310	-.292		
Percent of total annuals in canopy cover	.014	-.128	.056	-.651	.626	-.128	
Percent of total cryptogams in canopy cover	.093	-.471	.086	.229	.411	-.471	.186

* r values greater than .666 are significant at .05 level.

** r values greater than .798 are significant at .01 level.

growth-forms. A highly significant negative correlation existed between the cover of shrubs and the perennial grasses.

The results of correlation analysis probably reflect the impoverishment of the community in terms of numbers of species and volume of space occupied by each species. Shadscale was practically the only shrub present. The only grass of real importance was galleta grass. The correlation analysis was not productive in some respects since it only revealed that increase in cover of shadscale resulted in an increase in total shrub cover. Also the increase of galleta grass resulted in the increase in the total cover of perennial grasses.

Soil characteristics. Soil analyses data for samples collected from four horizons that occurred throughout the root zone in nine different locations were computed and tested for each soil character individually. Variation in each soil character was expected between horizons and among locations (Table 6).

Difference in silt content was not significant among locations as well as between horizons. Differences in the amount of exchangeable sodium, moisture percentage at saturation, and content of both sand and lime, were found significant among locations as well as between horizons.

The pH of saturated soil paste was the only soil character that was significantly different among locations but not between horizons.

There were significant differences between horizons in the pH of a 1:5 soil-water suspension, base exchange capacity, thickness of horizon, saturation extract conductivity, one-third atmosphere moisture percentage, total soluble salts percentage, amount of exchangeable potassium, and content of each clay (0.002) and clay (0.005).

Table 6. Analyses of variance for soil characteristics of four different horizons in nine locations in the association of *Atriplex confertifolia*-*Hilaria jamesii*.

Source	D. F.	Thickness of horizon (in.)	pH (paste)	pH (1:5)	Base exchange capacity (me./ 100 g.)	Exchangeable K (me./ 100 g.)	Exchangeable Na (me./ 100 g.)	Exchangeable Na percentage	Total soluble salts percentage	Saturation extract conductivity (K x 10^3)	Moisture percentage at saturation	1/3 atmosphere moisture percentage	Lime percentage	Sand percentage	Silt percentage	Clay (0.002) percentage	Clay (0.005) percentage
					Mean squares								Mean squares				
Location	8	8.88	0.237**	0.338	25.57	0.037	0.201*	41.63	0.0060	2.65	120.92*	27.00	223.99**	640.53*	204.56	144.55	284.65
Horizon	3	548.04**	0.040	0.709*	96.59**	0.713**	2.272**	178.47**	0.0978**	65.23**	462.55**	125.08**	790.34**	1209.21**	234.88	530.00**	1050.62**
Error	24	8.05	0.015	0.163	15.83	0.021	0.073	22.33	0.0056	.205	36.09	20.64	31.18	243.55	100.26	65.85	135.58

* Indicates significance at the .05 level.

** Indicates significance at the .01 level.

These data show that differences in soil characters between the nine locations are relatively minor. Therefore, it may be concluded that the nine different locations are homogeneous at least for the soil characters investigated in this study.

Relationships between soil and plant characteristics. A simple correlation analysis between 6 characteristics of vegetation and 10 soil characteristics is displayed in each horizon of the soil profile.

A summary of simple linear correlation coefficients is presented in Table 21.

The total density was negatively correlated with the amount of exchangeable sodium in the gypsiferous horizon. The density of shadscale was negatively correlated with the amount of exchangeable potassium and base exchange capacity in the surface horizon and with total soluble salts in the lime zone.

Significant positive correlation existed between the total canopy cover and lime content in the gypsiferous horizon. Significant negative correlation occurred between the cover of shadscale and both base exchange capacity and amount of exchangeable potassium in the surface horizon and the total soluble salts in the lime zone. Significant positive correlation existed between the cover of shadscale and pH of saturated soil paste and saturation extract conductivity in the lime zone.

Significant positive correlations occurred between the cover of galleta grass and the amount of exchangeable potassium in the surface horizon, and the base exchange capacity in both surface and B2 horizons. The cover of galleta grass was negatively correlated with the amount of exchangeable sodium in the gypsiferous horizon.

In general, these data indicated that base exchange capacity, amount of exchangeable potassium, total soluble salts, pH of saturated soil paste and saturated extract conductivity were correlated with the different vegetation characteristics more than the other soil characters.

The association of Atriplex nuttallii var. nuttallii-Hilaria jamesii (Atripletum nuttallae)

The stratification of this association is similar to that of the previous one. The vegetation is divided into three different strata, shrub, herbaceous and moss layers.

This association is characterized by having a relatively higher number (17) of species than any of the other associations. The shrubs are more abundant than other species (Figure 6). The general appearance of this association is shown in Figure 7.

Phytosociological characteristics. As it is shown in Table 3 saltbush has the highest frequency, constancy and fidelity in this association. Galleta grass has also a high frequency and constancy but its fidelity is lower than that of shadscale due to its occurrence in other communities.

Artemisia spinescens (bud sagebrush) and *Sphaeralcea grossulariaefolia* (globe mallow) have high constancies but low frequencies. Their fidelities are lower than the saltbush because of their occurrence in other communities.

A tabulation of quantitative data is shown in Table 7. The total basal cover was 4.59 percent and the total canopy cover was 6.20 percent. Saltbush contributed 53.58 percent of the total basal cover and 54.31 percent of the total canopy cover. Galleta grass was rated next to saltbush having values of 36.14 percent of the total basal cover and 28.75 percent of the total canopy cover. It also had the highest

Figure 7. The association of *Atriplex* *nuttallii* var. *nuttallii*-*Hilaria* *jamesii*.

Table 7. Mean values of vegetation characteristics for nine locations of the association of *Atriplex nuttallii* var. *nuttallii*-*Hilaria jamesii*.

	Density[a] (No. of plants/ sq.ft.)	Total basal cover	% Composition of basal cover	Total canopy cover	% Composition of canopy cover
Atriplex confertifolia	0.0033	0.0367	0.7990	0.0789	1.2436
Atriplex nuttallii var. *nuttallii*	0.0978	2.4611	53.5837	3.3644	54.3074
Atriplex corrugata	0.0047	0.0814	1.7723	0.1089	1.7578
Gutierrezia sarothrae	0.0020	0.0056	0.1219	0.0233	0.3761
Tetradymia glabrata	0.0011	0.0033	0.0718	0.0211	0.3406
Artemisia spinescens	0.0167	0.0751	0.6351	0.1792	2.8926
Eurotia lanata	0.0080	0.0418	0.9101	0.1411	2.2776
Eriogonum microthecum	0.0027	0.0311	0.6771	0.1333	2.1517
Total for shrubby plants	0.1363	2.7361	59.5710	4.0502	65.3774
Opuntia polyacantha	0.0004	0.0250	0.5443	0.0250	0.4035
Total for succulents	0.0004	0.0250	0.5443	0.0250	0.4035
Aster xylorrhiza	0.0140	0.0159	0.3462	0.0592	0.9556
Sphaeralcea grossulariaefolia	0.0100	0.0170	0.3701	0.0424	0.6844
Total for perennial forbs	0.0240	0.0329	0.7163	0.1016	1.6400
Hilaria jamesii	0.6511	1.6600	36.1419	1.7811	28.7501
Oryzopsis hymenoides	0.0142	0.0514	1.1191	0.0944	1.5238
Total for perennial grasses	0.6653	1.7114	37.2610	1.8755	30.2739
Eriogonum inflatum	0.0553	0.0462	1.0059	0.0944	1.5238
Malcolmia africana	0.0016	0.0011	0.0239	0.0033	0.0533
Bromus tectorum	0.0038	0.0011	0.0239	0.0059	0.0952
Total for annuals	0.0607	0.0484	1.0537	0.1036	1.6723
Mosses	0.0000	0.0389	0.8469	0.0389	0.6279
Lichens	0.0000	0.0003	0.0065	0.0003	0.0048
Total for cryptogams	0.0000	0.0392	0.8534	0.0392	0.6327
Total for association	0.8867	4.5930	99.9997	6.1951	99.9998

[a] Values do not represent actual measurements but result from computing fractional value from one plot of the nine stands sampled.

density value (0.65) in this association. These two species contributed 89.73 percent of the total basal cover and 83.06 percent of the total canopy cover in average. Both bud sagebrush and globe mallow contributed 1.64 percent of the total basal cover and 4.32 percent of the total canopy cover. In general, perennial forbs, annuals, succulents and cryptogams contributed lower values than the perennial grasses and shrubby vegetation (Table 7).

Relationships between vegetation characteristics. Table 8 shows a summary of simple correlation coefficients between the percent cover contributed by two prominent species as well as the different growth-forms.

Significant negative correlations occurred between perennial grasses and each of shrubs and annuals. The shrubs were positively correlated with annuals. These relationships revealed that the presence of shrubs was reduced by the cover of perennial grasses but increases the cover of annuals.

A significant positive correlation between galleta grass and the total perennial grasses. This relationship was expected since galleta grass was the only important perennial grass. However, such relationship did occur between the saltbush and the total shrub cover because of the presence of other shrub species.

Soil characteristics. Analyses of variance for the various soil characters obtained from three different horizons in nine locations are presented in Table 9.

Differences in each of the amount exchangeable sodium and lime content were found to be not significant among locations as well as between horizons.

Table 8. Correlation coefficients between vegetation characteristics of the association of Atriplex nuttallii var. nuttallii-Hilaria jamesii.

	% of saltbush in canopy cover	% of galleta grass in canopy cover	% of total shrubs in canopy cover	% of total succulents in canopy cover	% of total perennial forbs in canopy cover	% of total perennial grasses in canopy cover	% of total annuals in canopy cover
Percent of galleta grass in canopy cover	-.614						
Percent of total shrubs in canopy cover	.586	-.884**					
Percent of total succulents in canopy cover	-.020	.187	-.239				
Percent of total perennial forbs in canopy cover	.265	-.667*	.359	-.377			
Percent of total perennial grasses in canopy cover	-.610	.979**	-.943**	.157	.522		
Percent of total annuals in canopy cover	.568	-.821**	.688*	-.108	.381	-.841**	
Percent of total cryptogams in canopy cover	-.273	.289	-.412	.350	-.396	.253	.015

* r values greater than .666 are significant at .05 level.
** r values greater than .798 are significant at .01 level.

Table 9. Analyses of variance for soil characteristics of three different horizons in nine locations in the association of *Atriplex nuttallii* var. *nuttallii*-*Hilaria jamesii*.

Source	D. F.	Thickness of horizon (in.)	pH (paste)	pH (1:5)	Base exchange capacity (me./ 100 g.)	Exchangeable K (me./ 100 g.)	Exchangeable Na (me./100g.)	Exchangeable Na percentage
					Mean squares			
Location	8	4.40	0.043	0.060	26.47*	0.0045	1.90	477.07*
Horizon	2	747.15 **	0.112*	0.389**	51.92**	0.4089**	4.58	153.82
Error	16	6.273	0.022	0.026	6.86	0.0050	2.03	130.82

Table 9. Continued.

Total soluble salts percentage	Saturation extract conductivity (K x 10^3)	Moisture percentage at saturation	1/3 atmosphere moisture percentage	Lime percentage	Sand percentage	Silt percentage	Clay (0.002) percentage	Clay (0.005) percentage
					Mean squares			
0.0089	8.28	65.40	27.82	13.60	420.12**	137.33**	175.59*	363.95**
0.0963**	56.46**	476.78**	267.11**	199.86	815.59**	60.11	601.37**	821.37**
0.0073	7.81	23.19	10.19	84.43	71.18	26.36	56.75	61.70

* Indicates significance at the .05 level.

** Indicates significance at the .01 level.

Differences in silt content and exchangeable sodium percentage were significant among locations but not between the various horizons.

Differences in base exchange capacity, and content of sand, clay (0.002) and clay (0.005) were significant among locations as well as between horizons.

A large number of soil characters were significantly different between horizons but not among locations. These soil characters were the pH of saturated soil paste, pH of a 1:5 soil-water suspension, the thickness of horizons, amount of exchangeable potassium, total soluble salts percentage, one-third atmosphere moisture percentage and saturation extract conductivity.

These data show that six out of sixteen soil characters are significantly different between locations. Therefore, it is likely assumed that the nine different locations which are sampled for this association are not heterogeneous in most of their soil characters.

Relationships between plant and soil characteristics. Various soil characteristics obtained from each of the three different horizons that occurred throughout the root zone were correlated with different vegetation characteristics to determine their relationships. A summary of simple linear correlation coefficients is presented in Table 22.

Total density was positively correlated with the amount of exchangeable potassium in the gypsiferous horizons. The density of saltbush showed positive correlation with both base exchange capacity and saturated extract conductivity in the gypsiferous horizon, and with the amount of exchangeable potassium in the shale horizon. This density also showed a significant negative correlation with the pH of a 1:5 soil-water suspension obtained from the gypsiferous horizon.

The total canopy cover was positively correlated with the base exchange capacity in the gypsiferous horizon and with the total soluble salts in the shale horizon. A highly significant negative correlation existed between the cover of saltbush and pH of saturated soil paste obtained from gypsiferous horizon. A significant negative correlation occurred between the cover of galleta grass and lime content in each of the three horizons as well as the amount of exchangeable potassium in the shale horizon.

These data showed that lime content, base exchange capacity, saturated extract conductivity, pH of saturated soil paste, pH of a 1:5 soil-water suspension, total soluble salts and the amount of exchangeable potassium affected the vegetation characteristics of this community more than the other soil characters investigated.

The association of Atriplex nuttallii var. gardneri-Aster xylorrhiza (Atripletum gardnerae)

The stratification of this association differs from the other three communities in that only two strata occur, the shrub and the herbaceous layer. Neither moss nor succulent plants occur in this association (Figure 8).

Figure 6 shows that 13 species occur in this association with shrubs having the highest number.

Phytosociological characteristics. Table 3 shows that saltsage has the highest frequency, constancy, and fidelity in this association. Woody aster has a rather high frequency and constancy but its fidelity is lower than that of saltsage because of its occurrence in other communities. The bud sagebrush and Eriogonum inflatum (desert trumpet) have high constancies but low frequencies. Their fidelities are lower than the saltsage because of their occurrence in other species.

Figure 8. The association of *Atriplex* *nuttallii*-var. *gardneri*-*Aster* *xylorrhiza*.

A tabulation of quantitative data is presented in Table 10. The total basal cover was 3.22 percent and the total canopy cover was 6.21 percent. Saltsage contributed 74.90 percent of the total basal cover, and 65.72 percent of the total canopy cover. It also had the highest density value (0.25) in this association. Woody aster composed 6.73 percent of the total basal cover and 11.20 percent of the total canopy cover. These two species contributed 81.63 percent of the total basal cover and 76.92 percent of the total canopy cover.

Bud sagebrush composed 4.55 percent of the total basal cover and 7.34 percent of the total canopy cover. Desert trumpet contributed 4.02 percent of the total basal cover and 6.57 percent of the total canopy cover.

The perennial grasses and annuals contributed lower values of density, canopy cover and basal cover than the perennial forbs and shrubs.

Relationships between vegetation characteristics. Table 11 shows a summary of simple correlation coefficients between the percent cover composition of the prominent species as well as the different growth-forms. A significant negative relationship occurred between annuals and the shrubs. Therefore, the presence of shrubs decreased the cover of annuals.

The significant positive correlation between the saltsage and the total shrub cover could be explained by the fact that the saltsage was the most important shrubby species. The same relationship occurred between the woody aster and the total perennial forbs. The woody aster was the most abundant perennial forb.

Table 10. Mean values of vegetation characteristics for nine locations of the association of *Atriplex nuttallii* var. *gardneri*-*Aster xylorrhiza*.

Species	Density[a] (no. of plants/ sq. ft.)	Total basal cover	% Composition of basal cover	Total canopy cover	% Composition of canopy cover
Atriplex nuttallii var. *nuttallii*	0.0018	0.0311	0.9653	0.0589	0.9485
Atriplex nuttallii var. *gardneri*	0.2456	2.4133	74.9030	4.0811	65.7214
Atriplex corrugata	0.0007	0.0570	1.7691	0.0656	1.0564
Artemisia spinescens	0.0636	0.1467	4.5532	0.4556	7.3369
Eurotia lanata	0.0047	0.0078	0.2421	0.0367	0.5910
Eriogonum microthecum	0.0231	0.0278	0.8628	0.0889	1.4316
Total for shrubby plants	0.3395	2.6837	83.2955	4.7868	77.0858
Aster xylorrhiza	0.2322	0.2167	6.7258	0.6956	11.2018
Sphaerolcea grossulariaefolia	0.0024	0.0013	0.0403	0.0289	0.4654
Total for perennial forbs	0.2346	0.2180	6.7661	0.7245	11.6672
Hilaria jamesii	0.0153	0.1844	5.7233	0.2700	4.3480
Oryzopsis hymenoides	0.0042	0.0051	0.1583	0.0114	0.1836
Total for perennial grasses	0.0195	0.1895	5.8816	0.2814	4.5316
Eriogonum inflatum	0.0958	0.1296	4.0225	0.4078	6.5671
Malcolmia africana	0.0002	0.0000	0.0000	0.0003	0.0048
Bromus tectorum	0.0007	0.0011	0.0341	0.0089	0.1433
Total for annuals	0.0967	0.1307	4.0566	0.4170	6.7152
Total for association	0.6903	3.2219	99.9998	6.2097	99.9998

[a] Values do not represent actual measurements but result from computing fractional value from one plot of the nine stands sampled.

Table 11. Correlation coefficients between vegetation characteristics of the association of *Atriplex nuttallii* var. *gardneri*-*Aster xylorrhiza*.

	% of saltsage in canopy cover	% of woody aster in canopy cover	% of total shrubs in canopy cover	% of total perennial forbs in canopy cover	% of total perennial grasses in canopy cover
Percent of woody aster in canopy cover	-.431				
Percent of total shrubs in canopy cover	.769*	-.384			
Percent of total perennial forbs in canopy cover	-.457	.981**	-.378		
Percent of total perennial grasses in canopy cover	-.185	-.614	-.366	-.573	
Percent of total annuals in canopy cover	-.778*	.462	-.979**	.443	.202

* r values greater than .666 are significant at .05 level.

** r values greater than .798 are significant at .01 level.

Soil characteristics. Analyses of variance for soil characteristics of three different horizons in nine locations are presented in Table 12.

Differences in each of the pH of saturated soil paste, moisture percentage at saturation, and the content of sand and silt were not significant among locations as well as between horizons.

The amount of exchangeable potassium, clay (0.005) content, and base exchange capacity is found to be significantly different among locations as well as between horizons. However, differences in lime content were significant among locations but not between horizons.

There were significant differences between horizons but not among locations in the following soil characters: pH of a 1:5 soil-water suspension, thickness of horizons, the amount and percentage of exchangeable sodium, total soluble salt percentage, one-third atmosphere moisture percentage, clay (0.002) content, and saturation extract conductivity.

Table 12 shows that four out of sixteen soil characters were significantly different among locations. Therefore, soil dominated by this association are likely to be similar.

Relationships between soil and plant characteristics. A summary of simple linear correlation between the plant and soil characteristics is presented in Table 23.

The total density is negatively associated with moisture percentage at saturation in the bottom shale (R2) horizon. The total basal cover was significantly correlated with the base exchange capacity of the bottom shale (R2) horizon. Also a significantly positive correlation existed between the total canopy cover and the amount of exchangeable

Table 12. Analyses of variance for soil characteristics of three different horizons in nine locations in the association of Atriplex nuttallii var. gardneri-Aster xylorrhiza.

Source	D. F.	Thickness of horizon (in.)	pH (paste)	pH (1:5)	Base exchange capacity (me./ 100 g.)	Exchangeable K (me./ 100 g.)	Exchangeable Na (me./100 g.)	Exchangeable Na percentage
					Mean squares			
Location	8	0.667	0.0068	0.0083	4.728**	0.0083*	0.0291	0.537
Horizon	2	1598.778**	0.3126	0.0633*	6.083**	0.0422**	0.3267**	5.815**
Error	16	2.486	1.4263	0.0121	0.429	0.0031	0.0222	0.607

Table 12. Continued

Total soluble salts percentage	Saturation extract conductivity (K x 10^3)	Moisture percentage at saturation	1/3 atmosphere moisture percentage	Lime percentage	Sand percentage	Silt percentage	Clay (0.002) percentage	Clay (0.005) percentage
				Mean squares				
0.0049	3.10	11.51	0.51	103.52**	21.17	23.58	18.58	42.34*
0.0862**	49.84**	3.59	12.50**	8.90	19.44	4.83	136.11**	293.37**
0.0028	2.71	9.88	1.79	2.65	10.03	10.40	8.86	13.50

* Indicates significance at the .05 level.

** Indicates significance at the .01 level.

potassium in the surface horizon as well as the base exchange capacity and the amount of exchangeable sodium in the bottom shale (R2) horizon.

The canopy cover of saltsage showed a significant positive correlation with moisture percent at saturation in the surface horizon and also with lime content in the upper shale (R1) horizon. The cover of saltsage was negatively correlated with the one-third atmosphere moisture percentage in the shale (R1) horizon. The cover of woody aster showed a significant negative correlation with the one-third atmosphere percentage obtained from the surface horizon.

These data showed that soil moisture constants, amount of exchangeable potassium, amount of exchangeable sodium, base exchange capacity and lime content are correlated with the vegetation characteristics of this association.

The community of Atriplex corrugata

On the basis of heights of the various growth-forms, the vegetation was divided into three strata, the shrub, herbaceous and moss layers.

Figure 6 shows the 11 different species occur in this association, with the annuals being more abundant than other species. This association has no succulent plants. The general appearance of this community is shown in Figure 2.

Phytosociological characteristics. Table 3 shows that mat saltbush the prominent species in this association, has the highest frequency, constancy and fidelity. Both woody aster and desert trumpet have high constancy but low frequency. Their fidelities are lower than mat saltbush because of their occurrence in other communities.

The total basal cover was 8.85 percent and the total canopy cover was 11.15 percent in average. Mat saltbush contributed 98.65 percent of the total basal cover and 95.63 percent of the total canopy cover. This species also had the highest density value (0.26) in this association. The perennial forbs and grasses, the annuals, and cryptogams contribute an average of 1.25 percent of the basal cover and an average of 3.84 percent of canopy cover (Table 13).

Relationships between vegetation characteristics. Table 14 shows a summary of simple linear correlation coefficients between the percent cover contributed by the different growth-forms as well as mat saltbush. A significant positive correlation occurred between mat saltbush and total shrubs. A significant negative correlation existed between mat saltbush and each of the perennial grasses, cryptogams, and annuals.

The shrub cover was negatively correlated with each of the perennial grasses, annuals, and cryptogams. A significant positive correlation existed between the annuals and each of the cryptogams and perennial grasses. Similar relationships reveal that: (1) the presence of the shrubs decreased the cover of perennial grasses, annuals, and cryptogams and (2) the perennial grasses, annuals and cryptogams were associated with each other.

Soil characteristics. Analyses of variance for the soil characteristics of five different horizons in nine locations are presented in Table 15.

Differences in base exchange capacity and both content of lime and silt were significant among locations but not between the various horizons.

There were significant differences among locations as well as between horizons in regard to the pH of saturated paste, pH of a 1:5 soil-water suspension, amount of exchangeable potassium, total soluble

Table 13. Mean values of vegetation characteristics from nine locations of the community of Atriplex corrugata

Species	Density[a] (no. of plants/ sq. ft.)	Total basal cover	% Composition of basal cover	Total canopy cover	% Composition of canopy cover
Atriplex corrugata	0.2598	8.7289	98.6450	10.6678	95.6342
Artemisia spinescens	0.0056	0.0056	0.0633	0.0478	0.4285
Eurotia lanata	0.0031	0.0037	0.0418	0.0111	0.0995
Total for shrubby plants	0.2685	8.7382	98.7501	10.7267	96.1622
Aster xylorrhiza	0.0153	0.0326	0.3684	0.1078	0.9664
Total for perennial forbs	0.0153	0.0326	0.3684	0.1078	0.9664
Oryzopsis hymenoides	0.0004	0.0000	0.0000	0.0014	0.0126
Total for perennial grasses	0.0004	0.0000	0.0000	0.0014	0.0126
Salsola kali var. tinuifolia	0.0011	0.0000	0.0000	0.0011	0.0099
Eriogonum inflatum	0.0667	0.0462	0.5221	0.2656	2.3810
Malcolmia africana	0.0044	0.0037	0.0418	0.0233	0.2089
Bromus tectorum	0.0002	0.0003	0.0034	0.0011	0.0099
Plantago tweedyi	0.0004	0.0000	0.0000	0.0000	0.0000
Total for annual herbs	0.0728	0.0502	0.5673	0.2911	2.6097
Mosses	0.0000	0.0278	0.3142	0.0278	0.2492
Total for cryptogams	0.0000	0.0278	0.3142	0.0278	0.2492
Total for community	0.3570	8.8488	100.0000	11.1548	100.0001

[a] Values do not represent actual measurements but result from computing fractional value from one plot of the nine stands sampled.

Table 14. Correlation coefficients between the vegetation characteristics of the community of <u>Atriplex corrugata</u> obtained from nine different locations.

	% of mat saltbush in canopy cover	% of total shrubs in canopy cover	% of total perennial forbs in canopy cover	% of total perennial grasses in canopy cover	% of total annuals in canopy cover
Percent of total shrubs in canopy cover	.974**				
Percent of total perennial forbs in canopy cover	-.641	-.503			
Percent of total perennial grasses in canopy cover	-.865**	-.921**	.343		
Percent of total annuals in canopy cover	-.838**	-.922**	.135	.881**	
Percent of total cryptogams in canopy cover	-.684*	-.819**	.0003	.912**	.914**

* r values greater than .666 are significant at the .05 level.

** r values greater than .798 are significant at the .01 level.

Table 15. Analyses of variance for soil characteristics of five different horizons in nine locations in the association of *Atriplex corrugata*.

Source	D. F.	Thickness of horizon (in.)	pH (paste)	pH (1:5)	Base exchange capacity (me./ 100 g.)	Exchangeable K (me./ 100 g.)	Exchangeable Na (me./100 g.)	Exchangeable Na percentage
				Mean squares				
Location	8	23.64	0.173**	0.115*	82.14**	0.035**	18.16	186.02
Horizon	4	195.24**	0.355**	0.592**	25.21	0.460**	183.26	2263.63**
Error	32	30.88	0.029	0.035	6.56	0.011	14.09	381.07

Table 15. Continued.

Total soluble salts percentage	Saturation extract conductivity (K x 10^3)	Moisture percentage at saturation	1/3 atmosphere moisture percentage	Lime percentage	Sand percentage	Silt percentage	Clay (0.002) percentage	Clay (0.005) percentage
				Mean squares				
0.943**	391.41	892.95**	28.63**	86.09**	140.96	71.29**	29.10	120.67
5.145**	2510.62**	2472.05**	96.01**	8.42	295.48**	28.44	284.52**	566.48**
0.236	240.85	256.13	5.88	17.50	73.86	17.91	33.82	61.79

* Indicates significance at the .05 level.

** Indicates significance at the .01 level.

salt percentage, saturation moisture percentage, and one-third atmosphere percentage.

Differences in the amount and percentage of sodium, thickness of horizons, saturation extract conductivity, and the content of sand and clay were significant between horizons but not among locations.

Nine of sixteen soil characters were significantly different between locations. This might be explained by the fact that soils under this community were developed on the alluvial outwash from the other three associations.

Relationship between soil and plant characteristics. In this association vegetation characteristics showed a few significant correlations with soil characters obtained from the five horizons that occurred throughout the root penetration.

A summary of simple linear correlation coefficients is presented in Table 24.

Significant negative correlations occurred between the total density and each of the lime content and pH of a 1:5 soil-water suspension obtained from the salt layer (Csa).

The total basal cover showed significant positive correlations with the pH of saturated soil paste in both the surface and shale (R) horizons as well as the amount of exchangeable sodium in the surface horizon. A significant positive correlation occurred between the total canopy cover and pH saturated soil paste in both the surface and shale (R) horizons. But significant negative correlation occurred between the total canopy cover and the pH of a 1:5 soil-water in the salt layer (Csa).

The cover of mat saltbush showed significant negative correlation with one-third atmosphere moisture percentage in the salt layer (Csa).

These data show that pH of saturated soil paste, pH of a 1:5 soil-water suspension, one-third atmosphere moisture percentage, lime content, and the amount of exchangeable sodium influence the different vegetation characteristics in this association.

Comparison Between Soil Characteristics of the Different Communities

The four plant communities are not only distinctly different in their floristic composition but also in their soil characteristics. The descriptions of the soil profiles reveal that: (1) the number of horizons varies between the different communities, (2) some, but not all, of the horizons are similar in their origin and development.

Analyses of variance were computed for the average values of each of the soil characteristics obtained from the entire soil profile in nine locations in each of the four plant communities. Also analyses of variance were computed for the different soil characters obtained from surface horizon which is the only comparable horizon between the four different communities.

Analyses of variance were also computed for the different soil characters obtained from the comparable horizons in the different communities.

Comparison between the four communities

Depth of soil profile. The depth of soil profile varied widely among the four different communities (Figure 4). An analysis of variance showed that differences in the depth of soil profiles were highly significant between the four communities (Table 16).

Table 16. Analyses of variance for mean values of each of the soil characteristics of the entire soil profile in nine locations of the four plant communities.

Source	D. F.	Depth of soil profile (in.)	pH (paste)	pH (1:5)	Base exchange capacity (me./ 100 g.)	Exchangeable K (me./ 100 g.)	Exchangeable Na (me./ 100 g.)	Exchangeable Na percentage
					Mean squares			
Community	3	11.26**	1.470**	1.598**	144.80**	0.0534**	147.61**	2761.23**
Error	32	2.23	0.021	0.033	8.24	0.0052	13.84	53.41

Table 16. Continued.

Total soluble salts percentage	Saturation extract conductivity (10^3 x K)	Moisture percentage at saturation	1/3 atmosphere moisture percentage	Lime percentage	Sand percentage	Silt percentage	Clay (0.002) percentage	Clay (0.005) percentage
				Mean squares				
4.156**	1054.10**	2260.86**	123.58**	90.47	2771.48**	1272.93**	656.26**	1476.02**
0.049	20.68	58.62	5.48	37.73	84.79	30.50	26.69	49.95

* Indicates significance at the .05 level.

**Indicates significance at the .01 level.

The thickness of the surface horizon also differed between the different communities and this difference was highly significant (Table 17).

Soils under the community of mat saltbush had the deepest soil profile with 58 inches average. The association of shadscale-galleta grass, the association of saltsage-woody aster and the association of saltbush-galleta grass followed in decreasing depth with 50, 43 and 36 inches, respectively (Figure 4).

pH of saturated soil paste. An analysis of variance showed that differences in mean values of pH (paste) were significant between communities (Table 16). There was also a highly significant difference in pH (paste) between the surface horizons of the four communities (Table 17).

An increase in pH (paste) with soil depth was evident in the association of shadscale-galleta grass as well as the association of saltsage-woody aster (Table 18).

A similar increase in the values of pH (paste) with soil depth was also noted in the community of mat saltbush except for the shale (R) horizon which showed a reverse relationship (Table 18) probably because of the lower value of the total soluble salt percentage in the shale horizon than that of the salt layer (Csa). However, soils under the association of saltsage-woody aster had their lowest pH (paste) in the gypsiferous horizons (Table 18).

pH of a 1:5 soil-water suspension. The variation in pH (1:5) among the different horizons in each association was slightly more than that of pH (paste).

Table 17. Analyses of variance for soil characteristics of Al horizon in nine locations of each of the four plant communities.

Source	D. F.	Thickness of horizon (in.)	pH (paste)	pH (1:5)	Base exchange capacity (me./ 100 g.)	Exchangeable K (me./ 100 g.)	Exchangeable Na (me./100g.)	Exchangeable Na percentage
					Mean squares			
Community	3	7.139**	0.1981**	0.903**	141.48**	0.0698*	2.004*	322.03
Error	32	0.528	0.0251	0.016	9.71	0.0173	0.585	154.61

Table 17. Continued

Total soluble salts percentage	Saturation extract conductivity (K x 10^3)	Moisture percentage at saturation	1/3 atmosphere moisture percentage	Lime percentage	Sand percentage	Silt percentage	Clay (0.002) percentage	Clay (0.005) percentage
				Mean squares				
0.0833**	26.23	581.85**	186.35**	120.46	4186.11**	165.43**	761.30**	1852.47**
0.0150	2.89	15.82	3.76	61.26	61.90	30.65	24.77	44.97

* Indicates significance at the .05 level.
** Indicates significance at the .01 level.

Table 18. Mean values for soil characteristics of the different horizons in nine locations of each of the four plant communities.

Plant community	Horizon	Thickness of horizon (in.)	pH (paste)	pH (1:5)	Base exchange capacity (me./100g.)	Exchangeable K (me./100g.)	Exchangeable Na (me./100g.)	Exchangeable Na percentage	Total soluble salt percentage	Saturation extract conductivity (K x10^3)
Shadscale-galleta grass	A1	3.9	7.7	9.1	9.8	0.72	0.31	3	0.05	1.97
	B2	8.2	7.7	9.2	14.9	0.89	0.43	3	0.06	1.37
	Cca	20.0	7.8	9.5	16.1	0.35	1.37	9	0.14	3.12
	Ccs	18.3	7.9	8.9	10.0	0.29	1.03	12	0.28	7.34
	Average		7.8	9.2	12.7	0.56	0.79	7	0.13	3.45
Saltbush-galleta grass	A1	2.8	7.6	8.6	16.1	0.67	0.31	9	0.12	2.84
	Ccs	12.0	7.5	8.2	11.3	0.31	0.33	3	0.11	3.06
	R	21.0	7.7	8.3	14.2	0.29	1.56	11	0.29	7.30
	Average		7.6	8.4	13.9	0.42	0.73	8	0.17	4.40
saltsage-woody aster	A1	3.1	7.4	8.3	16.7	0.59	0.27	2	0.17	3.04
	R1	10.6	7.5	8.3	16.9	0.58	0.30	2	0.18	3.26
	R2	29.0	7.8	8.4	18.3	0.47	0.62	3	0.34	7.22
	Average		7.6	8.3	17.3	0.55	0.40	2	0.23	4.51
Mat saltbush	A1	4.8	7.8	8.5	19.0	0.80	1.24	15	0.28	5.91
	B2	13.7	8.4	9.0	22.7	0.41	9.45	41	1.46	18.23
	A1.b	15.6	8.7	9.2	22.8	0.33	13.53	59	1.76	28.75
	Csa	9.2	8.7	9.0	20.9	0.22	9.36	44	2.25	51.35
	R	14.0	8.6	9.1	22.9	0.30	10.07	44	1.91	24.55
	Average		8.4	9.0	21.7	0.41	8.73	41	1.53	25.76

Table 18. Continued.

Plant community	Horizon	Moisture percentage at saturation	1/3 atmosphere percentage	Lime percentage	Sand percentage	Silt percentage	Clay (0.002) percentage	Clay (0.005) percentage
Shadscale-galleta grass	A	25	12.41	14.5	58	26	16	21
	B	32	15.16	13.0	51	23	27	34
	Cca	39	20.75	33.3	33	33	34	46
	Ccs	40	18.84	16.9	38	32	30	41
	Average	34	16.79	19.4	45	29	27	36
Saltbush-galleta grass	A	36	17.84	20.2	33	39	29	39
	Ccs	50	28.64	10.9	14	40	45	57
	R	43	22.00	17.3	19	44	38	52
	Average	43	22.83	16.1	22	41	37	49
Saltsage-woody aster	A1	42	23.28	20.9	9	58	32	52
	R1	41	21.15	18.9	4	57	40	61
	R2	40	21.34	19.9	4	57	40	61
	Average	41	21.92	19.9	6	57	37	58
Mat saltbush	A1	42	18.87	13.9	17	45	37	52
	B2	77	27.25	11.7	15	41	50	66
	A1.b	83	27.78	12.8	5	45	51	71
	Csa	79	26.76	14.1	6	45	50	70
	R	69	26.64	12.7	8	42	49	69
	Average	70	25.46	13.0	10	44	47	66

A highly significant difference in pH (1:5) existed between the four communities (Table 16). There was also significant differences in pH (1:5) between the surface horizons of the four communities (Table 17).

Base exchange capacity; milliequivalents per 100 grams soil. An analysis of variance showed that the mean values of base exchange capacity for the soil profiles were highly significant between the four communities (Table 16). Also highly significant differences occurred in the base exchange capacity of the surface horizons of the four communities (Table 17).

Exchangeable potassium; milliequivalents per 100 grams soil. An analysis of variance for the mean values of potassium content of the entire soil profile showed that significant difference occurred between the four communities (Table 16).

Differences in the amount of exchangeable potassium between the surface horizons of the different communities were also highly significant (Table 17).

In the association of saltbush-galleta grass as well as the association of saltsage-woody aster, the amount of exchangeable potassium decreased with depth (Table 18). This tendency also occurred in the community of mat saltbush except for salt horizon (Csa) which showed a reverse relationship (Table 18).

In the association of shadscale-galleta grass the surface horizon had a slightly lower value than the B2 horizon, then a decrease in the amount of exchangeable potassium occurred with increasing soil depth (Table 18).

Soils under the association of shadscale-galleta grass had the highest mean value for exchangeable potassium with 0.56 milliequivalents per 100 grams soil. The association of saltsage-woody aster, the association of saltbush-galleta grass and the community of mat saltbush followed in decreasing amounts with 0.55, 0.42, and 0.41 milliequivalents per 100 grams soil, respectively (Table 18).

Exchangeable sodium; millequivalents per 100 grams soil and exchangeable sodium percentage. Variability in both of the percentage and amount of exchangeable sodium among soils under the different plant communities is shown in Table 18. The means for both amount and percentage of exchangeable sodium obtained from the entire soil profiles were highly significantly different between the four communities (Table 16).

There was also significant difference in the amount of exchangeable sodium in the surface horizons between communities (Table 17).

In general, the amount of exchangeable sodium increased with depth in the association of saltbush-galleta grass as well as saltsage-woody aster. The same tendency occurred in the association of shadscale-galleta grass, except the gypsiferous horizon which showed the reverse relationship.

An increase in the amount of exchangeable sodium with depth occurred in the community of mat saltbush. But a reverse relationship occurred in the salt layer (Csa) and the shale (R) horizons because of their lower content of clay.

Soils under the community of mat saltbush averaged 8.73 milliequivalents of exchangeable sodium per 100 grams of soil which was the highest amount that occurred in any of the four communities. The association of shadscale-galleta grass, the association of saltbush-galleta grass and the association of saltsage-woody aster followed in decreasing amount with 0.79, 0.73 and 0.40 milliequivalents per 100 grams soil, respectively.

Total soluble salt percentage. The total soluble salt content of soils varied widely between the different communities (Table 18). Differences in the mean values of total soluble salt contents were highly significant between soils under the four communities (Table 16).

The content of total soluble salts in the surface horizon differed between the different communities and this difference was also highly significant (Table 17).

The content of total soluble salts increased with soil depth in the association of shadscale-galleta grass and the association of saltsage-woody aster. In general, this tendency of salt to accumulate in the deeper horizons occurred in soils dominated by the communities of mat saltbush except for the shale (R) horizon which had less soluble salt content than the salt layer. In the association of saltbush-galleta grass the gypsiferous horizon had slightly less soluble salt content than the surface horizon as well as the shale (R) horizon.

This pattern of distribution for total soluble salt was similar to that of pH of saturated soil paste (Table 18). This was expected since the presence of soluble salts in saline or saline-alkali soils affects the pH values.

Soils under the community of mat saltbush had the highest mean value for total soluble salts with 1.53 percent. The association of saltsage-woody aster, the association of saltbush-galleta grass and the association of shadscale-galleta grass followed in decreasing amounts with 0.23, 0.17 and 0.13 percent, respectively.

Saturation extract conductivity; millimhos per cubic centimeter. The mean values for saturation extract conductivity for soil profiles showed considerable variability between the four different communities (Table 18).

Analyses of variance for the saturation extract conductivity obtained from the surface horizon as well as the mean values for the entire soil profile showed that significant differences occurred between the different communities (Table 16 and 17).

The saturation extract conductivity increased with soil depth for the association of saltbush-galleta grass as well as the association of saltsage-woody aster. The same relationships occurred in the association of shadscale-galleta grass except for the surface horizon which had a higher value than B2 horizon. In the community of mat saltbush the saturation extract conductivity increased with depth except for the bottom horizon (Dr) which showed a reverse relationship.

One-third atmosphere moisture percentage and saturation moisture percentage. The values for both moisture constants obtained from the surface horizon widely differed between the different communities (Table 18) and these differences were highly significant (Table 17). Also the mean values obtained from the entire soil profile for these moisture constants were significantly different between soils dominated by the different communities (Table 16).

Soils under the community of mat saltbush had the highest values for both moisture constants. The association of saltbush-galleta grass, the association of saltsage-woody aster and the association of shadscale-galleta grass followed in decreasing values, respectively.

Lime percentage. The soils of the shadscale zone in southeastern Utah are calcareous. Because of low precipitation rates and limited leaching, the lime content of these soils is relatively high.

Analyses of variance for lime content in the surface horizon as well as the average values for the entire soil profile showed that no significant differences occurred between the different communities (Tables 16 and 17)

Sand content. The differences in sand content in the surface horizon as well as for the entire soil profile were significant between the four communities (Tables 16, 17 and 18).

Soil under the association of shadscale-galleta grass had the highest sand content followed in decreasing order by the association of saltbush-galleta grass and the community of mat saltbush and the association of saltsage-woody aster, respectively (Table 18).

This variation likely results from the fact the soils of these communities developed from parent materials of different origin.

Silt content. The difference in silt content in the surface horizon as well as for the entire soil profile were significant between the four communities (Tables 16, 17 and 18).

The association of saltsage-woody aster had the highest silt content followed in decreasing order by the community of mat saltbush, the association of saltbush-galleta grass and the association of shadscale-galleta grass, respectively (Table 18).

Clay content. The content of both clay (0.002) and clay (0.005) in the surface horizon were significantly different between communities (Table 16).

Soils under the community of mat saltbush had the highest clay content followed in decreasing order by the association of saltsage-woody aster, the association of saltbush-galleta grass and the association of shadscale-galleta grass, respectively (Table 18).

Comparisons between the gypsiferous horizons in the association of shadscale-galleta grass and the association of saltbush-galleta grass

It is believed that the gypsiferous horizon that occurs in both of these associations is developed from the same parent material. This horizon is deeper under the association of shadscale-galleta grass than under the association of saltbush-galleta grass. Therefore, it is subjected to less weathering.

Significant differences between the two associations occurred in thickness of horizon, pH of saturated soil paste, pH of a 1:5 soil-water suspension, the percentage and amount of exchangeable sodium, total soluble salts, saturation extract conductivity, percentage moisture at saturation, one-third atmosphere moisture percentage, and sand and clay (0.002) contents (Table 19). However, differences in base exchange capacity, amount of exchangeable potassium, and lime, silt, clay (0.005) contents were found to be not significant between these two associations (Table 19). Since eleven out of sixteen soil characters of the gypsiferous horizon were different between the three associations, it could be concluded that these associates were two separate entities.

Comparison between the bottom shale horizon in the association of shadscale-galleta grass, the association of saltsage-woody aster and the community of mat saltbush.

The bottom shale horizon in each of these associations originated from Mancos marine shale. The depth of this horizon varies between the

Table 19. Analysis of variance for the various soil characteristics of the gypsiferous horizon in nine locations of both the communities of _Atriplex confertifolia-Hilaria jamesii_ and _Atriplex nuttallii_ var. _nuttallii-Hilaria jamesii_.

Source	D. F.	Thickness of horizon (in.)	pH (paste)	pH (1:5)	Base exchange capacity (me./ 100 g.)	Exchangeable K (me./ 100 g.)	Exchangeable Na (me./ 100g)	Exchangeable Na percentage
				Mean squares				
Community	1	180.50**	0.881**	1.934*	7.35	0.0016	1.183*	355.56*
Error	16	7.75	0.059	0.255	8.80	0.0012	0.189	48.78

Table 19. Continued.

Total soluble salts percentage	Saturation extract conductivity (K x 10^3)	Moisture percentage at saturation	1/3 atmosphere moisture percentage	Lime percentage	Sand percentage	Silt percentage	Clay (0.002) percentage	Clay (0.005) percentage
				Mean squares				
0.1301**	82.35**	480.51*	431.79**	160.80	2520.60*	296.06	1088.89**	1216.89
0.0074	2.28	87.82	44.00	57.79	607.82	214.51	17.41	317.85

* Indicates significance at the .05 level.

** Indicates significance at the .01 level.

three communities (Figure 4). Significant differences in all soil characters were found between these three communities (Table 20).

These data show that three communities are distinctly different in their bottom shale horizon.

Habitat Patterns and Their Directional Changes

Habitat pattern

The detection of discontinuity and continuity in a given population poses a major methodology problem in biological research particularly in the field of ecology. Dansureau (1957) emphasized discontinuity between individual stands of vegetation. On the other hand, Gleason (1939) and Cain (1947) expressed their doubt that an association might exist as a real entity over any considerable area. They considered that the plant community had an individual nature and that it was a result of coincidence of interaction of environmental factors with its species. Curtis and McIntosh (1951) and Brown and Curtis (1952), using the individualistic concept as a starting point, had developed the concept of continuum which involves gradual variation from one stand to another.

If variation is continuous, classification must ultimately depend on subjective judgement (as does all biological classification). However, under natural conditions there is a tendency for entities to be clustered in a multidimensional system (Grieg-Smith, 1957).

A climax formation of vegetation has an evolutionary history. Every climax formation consists of few to many subdivisions that may be termed associations, each of which is characterized by one or more obvious species (Weaver and Clements, 1938). While the formation is recognized on the basis of physiognomy of the more prominent species,

Table 20. Analyses of variance for the various soil characteristics of the bottom shale horizon in nine locations of each of the *Atriplex confertifolia-Hilaria jamesii*; *Atriplex nuttallii* var. *nuttallii-Hilaria jamesii*; and *Atriplex corrugata* communities.

Source	D. F.	Thickness of horizon (in.)	pH (paste)	pH (1:5)	Base exchange capacity (me./ 100 g.)	Exchangeable K (me./ 100 g.)	Exchangeable Na (me./100g.)	Exchangeable Na percentage
					Mean squares			
Community	2	507.00**	2.263 *	1.668**	168.45**	0.0837**	244.31*	4144.78**
Error	24	13.33	0.0617	0.046	17.84	0.0114	7.30	201.30

Table 20. Continued.

Total soluble salts percentage	Saturation extract conductivity $(K \times 10^3)$	Moisture percentage at saturation	1/3 atmosphere moisture percentage	Lime percentage	Sand percentage	Silt percentage	Clay (0.002) percentage	Clay (0.005) percentage
				Mean squares				
7.611**	899.04**	2301.81**	75.07**	118.99*	506.78*	620.33**	387.11**	610.81**
0.167	33.47	190.09	10.02	27.25	112.88	47.33	57.52	103.82

* Indicates significance at the .05 level.

** Indicates significance at the .01 level.

plant communities are classified on the basis of phytosociologic characteristics. The climax species characterize the community and indicate the probable or actual presence of other associated species (Clements, 1920).

In the Zurich-Montpellier (Braun-Blanquet, 1932) concept of vegetation classification, floristic composition is recognized first and then almost exclusive emphasis is placed upon it, assuming that a certain association is a result of the biological-pedological climatic factors involved in a given habitat. The classification used by the Zurich-Montpellier school does have the merit of developing and stratifying given geobotanical areas into recognized vegetation units.

Becking (1957, p. 474) favors the floristic classification of association if it is based strictly upon the greatest floristic affinity. He writes, "Once an effective statistical check has been found for species fidelity and floristic affinity, the floristic classification of vegetation units, based upon statistical standards, may prove to be most satisfactory."

The classification of the salt-desert shrubs is tied up with the concept of the objective reality of the association over a large area. The statistical data on frequency in Table 3 show that no two locations (stands) within a given community are identically the same. On the other hand, the comparison of these data between the different communities indicates that there is a distinct difference in floristic composition greater than variation within a given community.

Each of the four different communities shows a definite recurrence which is evidence of a unique entity. Discontinuity between communities is not only floristic but also edaphic. A transitional zone whether sharp or broad is not part of the communities contributing to its existence but rather a product of both. It is not recognized as a stable unit of vegetation because of the lack of its recurrence as well as lack of homogeneity. The overlap or transitional zone of vegetation corresponds to the integration of the different edaphic conditions.

Directional changes between the four different communities

Since edaphic conditions varied to a greater or lesser degree within the study area different habitats are formed and become manifest as a mosaic of vegetation (Figure 9).

Figure 10 illustrates the syndynamic relations between the different communities. Syngenetical pattern is based on retrogressional changes that have occurred as a result of soil erosion process that had been active during recent geologic time. These relationships can be explained as follows: The association of shadscale-galleta grass is regarded as the climax for the shadscale zone in the study area. It dominates the three levels of the pediment remnants where soil remains more fully developed than are the soils associated with the other three communities. As it is shown in Figure 4 the soil has the following profile: A1 vesicular horizon, B2 prismatic, Cca massive lime zone, and Ccs massive gypsiferous horizon. Underlying the soil profile, below the zone of root penetration, is the Mancos Cretaceous marine shale.

The association of saltbush-galleta grass replaces the previous association in areas where the upper three layers are eroded and integrated into a shallow A1 vesicular horizon underlaid by Ccs, massive gypsiferous, and R, altered bedrock of shale (Figure 11). This

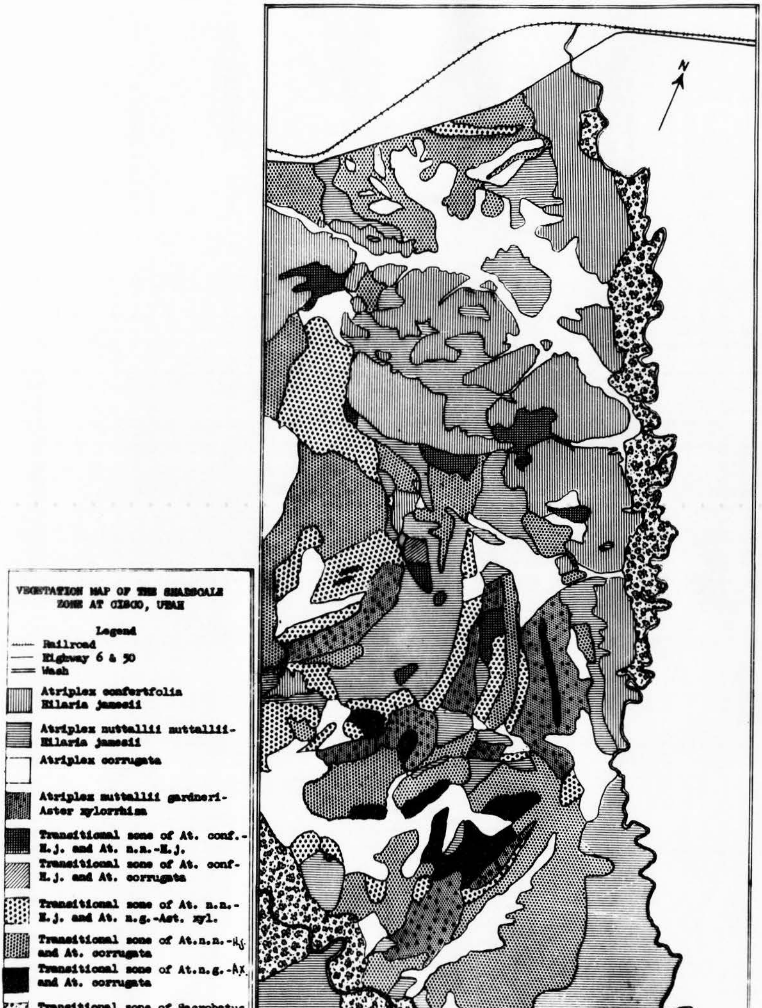

Figure 9. Vegetational map of the shadscale zone at Cisco, Utah.

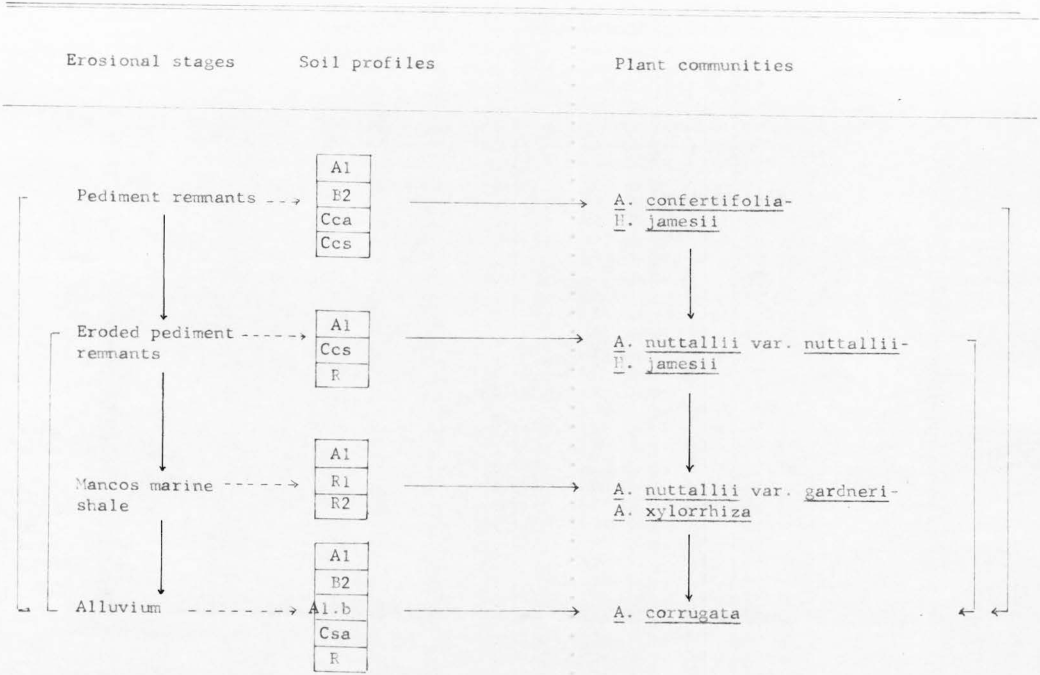

Figure 10. Syndynamic relations between the different communities as related to retrogressional stages due soil erosion.

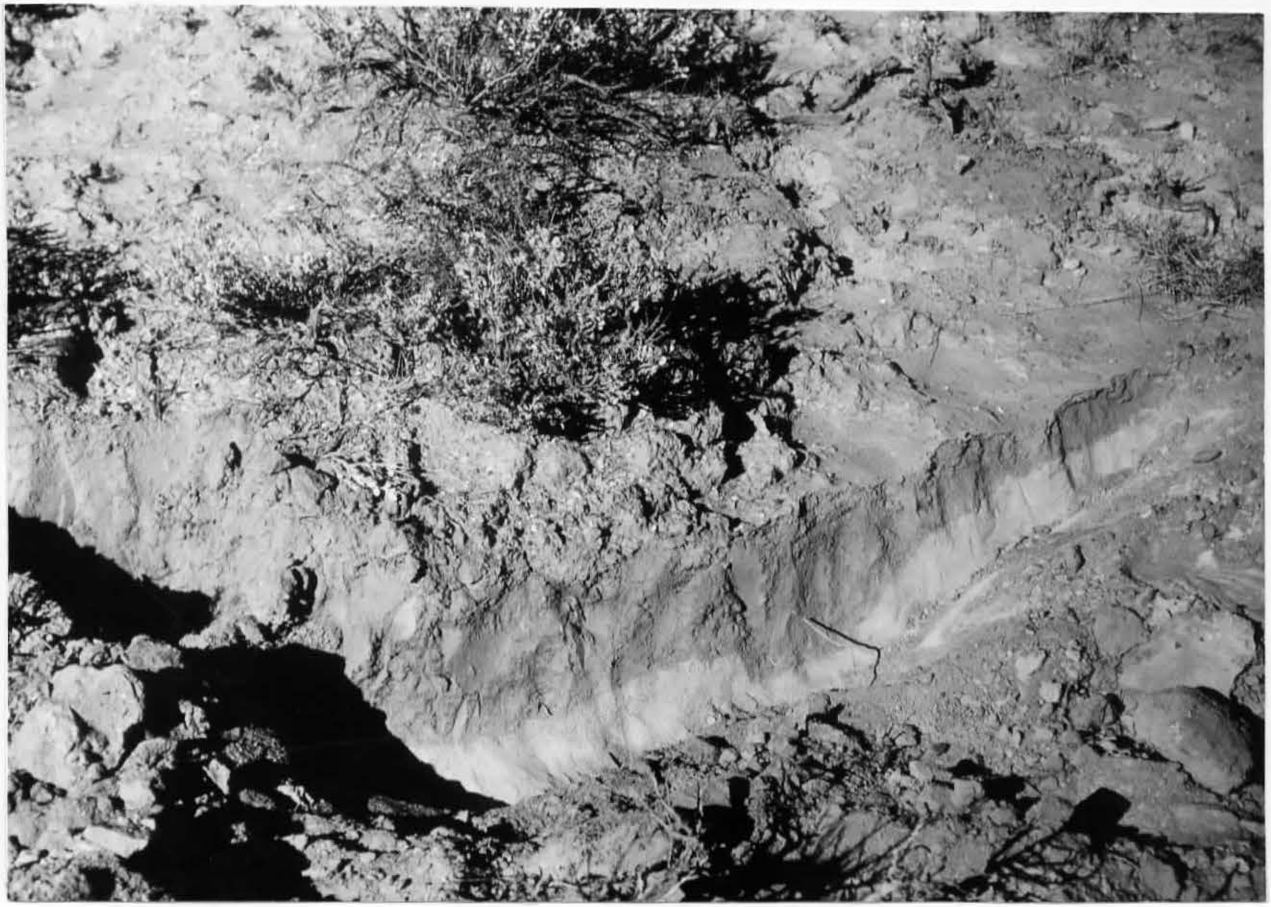

Figure 11. Excavated soil profile across an ecotone with the association of *Atriplex confertifolia*-*Hilaria jamesii* on the left side and the association of *Atriplex nuttallii* var. *nuttallii*-*Hilaria jamesii* on the right. The light grayish gypsiferous horizon is deeper under *Atriplex confertifolia* than in the adjacent area.

association always occupies elevations lower than the previous one whenever they are contiguous (Figure 12).

The ecotone between this association and the previous one varies in width (Figure 13) according to the degree of slope and severity of erosion. The directional change from the shadscale-galleta grass association to the saltbush-galleta grass association is retrogressional in nature.

The association of saltsage-woody aster occurs on slopes where the A1 horizon and the Ccs massive gypsiferous of the association of saltbush-galleta grass are eroded away and the Mancos marine shale is exposed at the surface. The A1 vesicular horizon is underlaid by altered bedrock shale (R1 and R2). This association always occupies elevations lower than that of saltbush-galleta grass wherever direct contact is made between these two associations. It does not form ecotones with the association of shadscale-galleta grass.

The community of mat saltbush is formed on alluvial deposits of material eroded away from the three previous associations and forms direct ecotones with each one of these associations. The soil profile is A1 vesicular horizon, B2 prisimatic, A1.b buried granular, Csa salt layer and R Mancos marine shale. The buried A1 horizon indicates that depositional rather than erosional processes contributed to the development of this habitat. In comparing this community with that of saltsage-woody aster, it is evident that this community is developed on soil material deposited over Mancos shale. This fact is supported by the presence of heavy clayey B2 horizon which is missing from the soil profile under the association of saltsage-woody aster.

Figure 12. A pediment remnant dominated by the association of *Atriplex confertifolia*-*Hilaria jamesii*. The association of *Atriplex nuttallii* var. *nuttallii*-*Hilaria jamesii* occupies the eroded slopes of the pediment remnant.

Figure 13. A sharp ecotone between the association of *Atriplex confertifolia-Hilaria jamesii* on the left and the association of *Atriplex nuttallii* var. *nuttallii-Hilaria jamesii* on the right.

In the study area it is assumed, based on geologic evidences, that soils on pediment remnants were older than those of Mancos shale. For this reason, the variation in edaphic factors of the pediment soils is expected to decrease and small differences in environmental factors between locations are eliminated or equalized by the reaction with vegetation. This assumption is supported by soil analyses which show that most differences in soil within the association of shadscale-galleta grass are not significant (Table 6).

Soil differences between locations are relatively greater in the saltbush-galleta grass associates than in the shadscale-galleta grass (Tables 6 and 9). This is expected since the former association was found on soil developed from eroded pediment remnants.

In the association of saltsage-woody aster most soil differences are not significant (Table 12). This might be due to the fact that the residual soils of this association were developed from the same parent material, the Mancos marine shale.

Within the community of mat saltbush the greater soil differences were more apparent than in the other three associations. Such variation is in accordance with the retrogressional sequences hypothesized for the study area because this community occupies soils being developed from deposited material from the other three associations. However, the term "community" is assigned to habitats dominated by mat saltbush rather than "association". Whether it is a seral community in balance with the prevailing environment or a stabilized association, may be a subject of investigation in the future.

SUMMARY AND CONCLUSIONS

Intensive field and laboratory studies during 1959, 1960 and 1961 were conducted on the shadscale zone of southeastern Utah to obtain basic information contributing to a better understanding of the factors influencing plant distribution.

In this study the fundamental units of the landscape were identified, characterized and correlated by the combined study and interpretation of vegetation and soil.

Four plant communities were identified on the basis of their floristic composition as follows: (1) the association of *Atriplex confertifolia*-*Hilaria jamesii* (shadscale-galleta grass), (2) the association of *Atriplex nuttallii* var. *nuttallii*-*Hilaria jamesii* (saltbush-galleta grass), (3) the association of *Atriplex nuttallii* var. *gardneri*-*Aster xylorrhiza* (saltsage-woody aster) and (4) the community of *Atriplex corrugata* (mat saltbush).

Phytosociological characteristics were determined at nine locations for each of the four communities. In each location, twenty plots (5 x 5 foot) were equally spaced on two transects. The phytosociological characteristics recorded were: density, basal cover, canopy cover and frequency. Each of the four communities shows a definite recurrance which is evidence of a unique entity.

The interrelationships between the cover of the prominent species as well as the different growth-forms were tested by simple linear correlation coefficients. In the shadscale-galleta grass association the results indicated that the presence of shrubs reduced the cover of perennial grasses.

In the saltbush-galleta grass association the presence of shrubs reduced the cover of each of perennial grasses and annuals.

In the saltsage-woody aster association, the presence of shrubs decreased the cover of annuals.

In the mat saltbush community, the presence of shrub cover decreased the perennial grasses, annuals and cryptogams.

Field investigations showed that each community was associated with characteristic soils. Therefore, edaphic factors were considered of primary importance in the distribution of these vegetation units.

To determine the differences in soil intensive studies were made in nine locations for each of the four communities. At each location trenches were dug to a depth of root penetration to allow a critical examination and description of soil profiles. Soil samples were collected from four horizons for the shadscale-galleta grass association; three horizons for the saltbush-galleta grass association; three horizons for the saltsage-woody aster association and five horizons for the community of mat saltbush.

Each sample was subjected to the following physical and chemical analyses: pH of saturated soil paste, pH of a 1:5 soil-water suspension, percentage exchangeable potassium, amount and percentage of exchangeable sodium, base exchange capacity, saturation extract conductivity, total soluble salt percentage, lime percentage, one-third atmosphere moisture percentage, moisture percentage at saturation and mechanical analysis.

For each soil characteristic, the mean value for the entire soil profile was computed. Significant differences between the four communities were found in all characteristics except lime content. Significant differences in each soil characteristic were found in the surface A1 horizon. Most soil characters from other comparable horizons differed significantly between the communities.

With the exception of the mat saltbush community, most of the soil characters were not significantly different between locations. This could be taken as evidence of the homogeneity of soils occupied by the same community. In the mat saltbush community, nine out of sixteen soil characters were found significant between locations. This could be taken as an evidence that soils under this community were not as homogeneous as in the other three associations.

In each community simple linear correlation coefficients between soil and vegetation characteristics were computed. The vegetation characters were: total density, density of prominent species, total basal cover, total canopy cover and the percent cover attributed by the prominent species.

In the shadscale-galleta grass association, the base exchange capacity, amount of exchangeable potassium, amount of exchangeable sodium, pH (paste), amount of total soluble salts, lime percentage, saturated extract conductivity showed significant correlation with the vegetation characteristics except total basal cover.

In the saltbush-galleta grass association, the base exchange capacity, saturated extract conductivity, pH (paste), pH (1:5), lime percentage, amount of exchangeable potassium and the total soluble salts percentage were significantly correlated with the vegetation characteristics except the total basal cover.

In the saltsage-woody aster association, the amount of exchangeable potassium, moisture contents, base exchange capacity, lime percentage and amount of exchangeable sodium showed significant correlation in the vegetation characteristics except the density of saltsage.

In the mat saltbush community, the pH (paste), pH (1:5), one-third atmosphere moisture percentage and the amount of exchangeable sodium were significantly correlated with the vegetation characteristics except the density of mat saltbush.

The syndynamic pattern of the four communities supported by edaphic and geologic evidences shows that the study area has been subjected to several cycles of soil erosion. The directional changes between the four communities are influenced by the retrogressional processes to which the pediment remnants and the Mancos bedrock shale are subjected. The pediment remnants are vegetated by the association of shadscale-galleta grass. On eroded sites of the pediment remnants this association is replaced by the saltbush-galleta grass association. The saltsage-woody aster association occupies area where the pediment remnants are eroded away and the Mancos marine shale is exposed to the ground surface. The community of mat saltbush dominates the alluvial deposits from the three previous associations.

The value of the four communities as indicators of soil conditions in the shadscale zone of southeastern Utah is well recognized. The shadscale-galleta grass association was found to occupy coarse-textured soils suggesting that this association is adapted to soils of low water holding capacity. Soils under this association were non-alkali throughout the soil profile. They were non-saline in the surface 2.5 feet but saline at greater depths. This association is indicative that a distinct lime zone 9 to 16 inches in thickness occurred from 15 to 29 inches below the soil surface.

Soils under the saltbush-galleta grass association were loamy and non-alkali throughout the soil profile. They were non-saline in the surface 15 inches but saline at greater depths. This association was a reliable indicator that a gypsiferous horizon 7 to 17 inches in thickness occurred from 2 to 4 inches below the soil surface.

The association of saltsage-woody aster occurred on fine-textured soils that were non-alkali throughout the soil profile. The soils were non-saline in the first foot but saline at greater depths.

The community of mat saltbush was growing on heavy-textured soils that were saline-alkali throughout the profile. The salinity and the amount of exchangeable sodium in the surface 5 inches showed a slight variability. However, this variability does not limit the use of this association as an indicator of saline-alkali soils.

A reconnaissance of approximately 200 square miles around the area was undertaken to investigate the occurrence of the four communities and their associated soils. This reconnaissance revealed that these habitat types could be recognized on the basis of vegetation and soil information obtained from the intensive survey of the study area. Therefore, the results obtained from the study area might be expanded to the entire shadscale zone throughout the Colorado Plateau Province in southeastern Utah.

The subdivision of landscape into its natural units referred to as habitat types, provides a better understanding of the landscape and subsequently enables a widespread application of synecological and phytosociological knowledge to land management problems.

However, the procedure undertaken in this study if followed in identifying the different plant communities in other areas of the shadscale zone is likely to provide comparable results and valuable information for better understanding of the entire shadscale zone.

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APPENDIXES

APPENDIX I

List of Plant Names used in the Text

SCIENTIFIC NAME	COMMON NAME
Artemisia spinescens Eaton	bud sagebrush
Artemisia tridentata Nutt.	big sagebrush
Aster xylorrhiza Torr. & Gray	woody aster
Astragalus canadensis L.	Canada milkvetch
Atriplex confertifolia (Torr. & Frem.) Wats.	shadscale
Atriplex corrugata Wats.	mat saltbush
Atriplex nuttallii var. *gardneri* (Moquin.) H. & C.	saltsage
Atriplex nuttallii var. *nuttallii* Wats.	saltbush
Bromus tectorum L.	cheatgrass
Eurotia lanata (Pursh) Moquin.	winterfat
Eriogonum inflatum Torr. & Frem.	desert trumpet
Eriogonum microthecum Nutt.	slender buckwheatbrush
Gutierrezia sarothrae (Pursh) Britt. & Rushy.	snakeweed
Hilaria jamesii (Torr.) Benth.	galleta grass
Juniperus osteosperma (Torr.) Little.	Juniper
Malcolmia africana (L.) R. Br.	Malcolmia
Opuntia polyacantha Haw.	prickly pear
Oryzopsis hymenoides (Roem. & Shult.) Ricker	Indian ricegrass
Plantago tweedyi Gray	tweedy plantain
Salsola kali var. *tenuifolia* Tausch.	Russian thistle
Sarcobatus vermiculatus (Hook) Torr.	greasewood

Sclerocactus whipplei (Engelm. & Bigelow) Britt. & Rose	cactus
Sphaeralcea grossulariaefolia (Hook. & Arm.) Rybd.	globe mallow
Tetradymia glabrata Gray	littleleaf horsebrush

APPENDIX 2

Profile Description of Soils under the Association of Atriplex confertifolia-Hilaria jamesii

The Mesa series consists of deep gravelly medium textured, calcareous well drained Sierozem soils, that have developed from pediment remnants on three different levels. Underlying the gravelly remnants is the original bedrock of cretaceous marine shale (Mancos shale).

The Mesa series is associated with Chipeta and Chipeta like soils having direct contact boundaries with them but not with the eroded Chipeta soils.

West of Cisco the Mesa soils occur at elevations ranging from about 4400 to 4200 feet above sea level.

I. Soil profile description: Mesa gravelly sandy clay loam.

A1 0-3" Light brown (7.5 YR 6/4), gravelly sandy clay loam, dark brown (7.5 YR 4/4) moist; weak fine platy and vesicular structure; loose dry; friable moist; slightly sticky and slightly plastic wet; calcareous; pH 8 (paste) and 8.3 (1:5); fine grass roots; few fine pores; clear smooth boundary; 3-5 inches thick.

B2 3-14" Brown (7.5 YR 4/5) dry, clay loam, yellowish brown (5 YR 5/4) moist; massive or weak coarse prismatic breaking down to weak fine granular structure; slightly hard dry; friable moist; slightly sticky and slightly plastic wet; calcareous; pH 8 (paste) and 8.9 (1:5); abundant fine roots; medium fine pores; diffuse wavy boundary; 5-11 inches thick.

Cca 14-42" Very pale brown, (10 YR 7.5/3) dry; clay loam, pale brown, (10 YR 6/3) moist; massive; slightly hard dry; friable moist; slightly sticky and slightly plastic wet; calcareous; pH 7.7 (paste) and 7.7 (1:5); abundant medium size roots; diffused irregular boundary; 15-28 inches thick.

Ccs 42-61+"Light brown gray (2.5 YR 7/2) dry, silty clay loam, very pale brown (10 YR 7/3) moist; massive; hard dry; friable moist; slightly sticky and non plastic wet; gypsiferous; pH 8.1 (paste) and 8.0 (1:5); very few roots in the portion; clear irregular boundary; 15-30+ inches thick.

II. Range in Characteristics: The dry color of the first horizon ranges from (10 YR 5/3.5) to (10 YR 6/4) with most values of (10 YR 6/4). The moist color ranges from (10 YR 4/3) to (10 YR 4/4) with an average of (10 YR 4/4). One profile was recorded having a color of (7.5 YR 4/5) and (7.5 YR 4/4) moist. Less variation in color for the rest of the horizons have been recorded. Texture and structure have little or no variation in the acreage that has been mapped. The depth of the gypsiferous horizon ranges from 5-21 inches.

III. Topography: The pediment remnants at three levels represent different cycles of erosion. The levels generally face the south and there slope from 1 to 6 percent.

IV. Drainage and Permeability: Mesa soils are moderately well drained. Runoff is medium to rapid.

APPENDIX 3

Profile Description of Soils under the Association of Atriplex nuttallii var. nuttallii-Hilaria jamesii

The Chipeta series are shallow, pale brown, medium textured, gypsiferous, moderately well drained, Sierozem soils, that have developed from pediment remnants. Underlying the eroded pediment is the original bedrock of Cretaceous marine shale (Mancos shale).

The Chipeta soils are associated with Mesa, eroded phase of Chipeta and Chipeta like soils. They occur in areas that were once occupied by Mesa soils which were subjected to erosional processes and which resulted in the removal of surface roughly equivalent to the upper three calcareous horizons, leaving a thin light brownish calcareous horizon underlaid by a gypsiferous layer.

I. Soil profile description: Chipeta clay loam

A1	0-2"	Brown (10 YR 5/3) dry, clay loam, dark yellowish brown (10 YR 4/4) moist; weak fine granular structure; loose dry, friable moist, sticky and plastic wet; calcareous; pH 7.8 (paste) and 8.0 (1:5); abundant fine roots; clear wavy boundary; 2-4 inches thick.
Ccs	2-12"	Light gray (2.5Y 7/2) dry, clay, light brownish gray (2.5Y 6/2) moist; massive; soft dry, firm moist; sticky and slightly plastic wet; gypsiferous; pH 7.7 (paste) and 7.8 (1:5); few medium pores; gradual irregular boundary; 7-16 inches thick.

R 12-34+" Grayish brown (2.5Y 5/2) dry, clay loamy shale, very dark grayish brown (2.5Y 3/2) moist, strong medium platy structure; slightly hard dry, very sticky and very plastic wet; gypsum crystals imbedded in partly weathered shale; pH 7.5 (paste) and 7.8 (1:5); roots in the upper portion diffused irregular boundary, 18-33+ inches thick.

II. Range in Characteristics: The color of the dry surface soil ranges from (10 YR 7/3) to (10 YR 5/3) and for the moist soil from (10 YR 5/3) to (10 YR 3/4). The amount and the size of the gypsum crystals vary in rather narrow range.

III. Topography: Eroded terraces of pediment remnant, rolling undulating and smooth relief. Slope ranges from 3 to 40 percent.

IV. Drainage and Permeability: The Chipeta soils are moderately well drained. Surface runoff is medium to rapid, permeability is moderately slow.

APPENDIX 4

Profile Description of Soils under the Association of Atriplex nuttallii var. gardneri-Aster xylorrhiza

The eroded phase of Chipeta series are shallow, light brownish gray, medium textured, gypsiferous, moderately well drained Sierozem soil that have developed in place of marine Cretaceous shale (Mancos shale).

These soils are associated with Chipeta and Chipeta like soils, forming direct boundaries with them. In the study area west of Cisco, Utah, these soils do not form direct boundaries with Mesa series.

I. Soil profile description:

A1	0-3"	Light brownish gray (2.5Y 6/2) dry, silty clay loam, olive brown (2.5Y 4/4) moist; vesicular weak fine granular structure; loose dry, friable moist, sticky and plastic wet; gypsiferous; pH 7.9 (paste) and 7.9 (1:5); a very few fine roots; gradual wavy boundary; 3-4 inches thick.
R1	3-13"	Light brownish gray (2.5Y 6/2) dry, silty clay loam, olive brown (2.5Y 4/4) moist; moderate very fine platy shale; slightly hard dry; firm moist; very sticky and very plastic wet; gypsiferous; pH 7.4 (paste) and 7.8 (1:5); abundant roots; diffused irregular boundary, 9-13 inches thick.

R2 13-43" Light brownish gray (2.5Y 6/2) dry, silty clay loam, olive brown, very dark grayish brown (2.5Y 3/2); strong medium platy shale; very hard dry, very firm moist, very sticky and very plastic wet, gypsiferous; pH 7.9 (paste) 8.3 (1:5); very few roots in the upper few inches, diffused irregular boundary, 27-33 inches thick.

II. Range in Characteristics: The color of the dry surface ranges from (2.5Y 7/2) to (2.5Y 5/2) and the moist soil from (2.5Y 5/2) to (2.5Y 3/2).

III. Topography: Eroded slopes, rolling undulating and rough relief. Slope ranges from 10 to 36 percent.

IV. Drainage and Permeability: The eroded Chipeta soils are moderately well drained. Surface runoff is medium to rapid.

APPENDIX 5

Profile Description of Soils under the Community of Atriplex corrugata

The Chipeta like is shallow fine textured gypsiferous, moderately well drained Sierozem soil that have developed from the Cretaceous Mancos shale. This soil is mainly associated with Chipeta and the eroded phase of Chipeta and less frequently with Mesa soils.

I. Soil profile description:

A1 0-5" Pale brown (10YR 6/3) dry, silty clay loam, dark yellowish brown (10 YR 4/4) moist; weak fine granular structure; loose dry, friable moist, sticky and plastic wet; gypsiferous; pH 7.7 (paste) and 8.1 (1:5); very few roots; clear smooth boundary; 4-5 inches thick.

B2 5-20" Pale brown (10 YR 6/3) dry, heavy silty clay, brown (10 YR 5/3) moist; weak medium prismatic structure with a few gypsum crystals deep cracks very hard dry, firm moist; very sticky and plastic wet; gypsiferous; pH 8.4 (paste) 8.6 (1:5); a few root pores; clear smooth boundary; 11-19 inches thick.

A1.b 20-31" Gray brown (2.5Y 5/2) dry, silty loam, dark grayish brown (2.5Y 4/2) moist; moderate fine platy shale mixed with weak fine granular structure and gypsum crystals; hard dry; firm

		moist very sticky and plastic wet; gypsiferous; pH 8.5 (paste) 8.5 (1:5); a few roots; clean wavy boundary; 11-14 inches thick.
Csa	31-33"	Light brownish gray (2.5Y 6/2) dry silty clay and crystals mixed with abundant gypsum crystals; hard dry, firm moist, very sticky and plastic wet; gypsiferous; pH 7.6 (paste) and 8.3 (1:5); diffused wavy boundary; 2-12 inches thick.
R	33-38"	Light brownish gray (2.5Y 6/2) dry, silty clay, dark grayish brown (2.5Y 4/2) moist; strong medium platy shale; hard dry, firm moist, very sticky and very plastic wet; gypsiferous; pH 8.2 (paste) 8.6 (1:5); abrupt smooth boundary; 5-21 inches thick.

II. Range in Characteristics: The color of the dry surface ranges from (10 YR 6/3) to (10 YR 5/2) and the moist soil from (10 YR 4/2) to (10 YR 4/4). The thickness of last two horizons vary considerably between locations.

III. Topography: Gentle slopes to flats associated with drainage systems. Slopes range from 1 to 5 percent.

IV. Drainage and Permeability: The Chipeta like soils are moderately well drained. Surface runoff is medium and permeability is moderately slow.

Table 21. Correlation coefficients between soil factors of four different horizons and the vegetation characteristics of the association of *Atriplex confertifolia-Hilaria jamesii*.

Soil factors for the different horizons	Total density (no. of plants/ sq. ft.)	Density of shadscale (no. of plants/ sq. ft.)	% of total basal cover	% of total canopy cover	% of shadscale in canopy cover	% of galleta grass in canopy cover
Surface horizon (A1)						
pH (paste)	.160	-.173	.124	.063	-.125	.294
pH (1:5)	.365	-.044	.334	.354	-.037	.181
Base exchange capacity (me. / 100 g.)	.520	-.768*	.236	.032	-.891**	.838**
Exchangeable K (me. / 100 g.)	.451	-.687*	.205	-.046	-.857**	.821**
Exchangeable Na (me. / 100 g.)	.158	-.324	.017	-.156	-.607	.373
Total soluble salts percentage	-.143	.065	-.204	-.105	.053	-.036
Saturation extract conductivity ($K \times 10^3$)	-.449	.581	-.364	-.161	.568	-.508
Moisture percentage at saturation	.494	-.416	.155	.201	-.558	.509
1/3 atmosphere moisture percentage	-.075	-.304	.414	.223	-.505	.060
lime percentage	.048	.507	.318	.601	.271	-.411

Table 21. Continued.

Soil factors for the different horizons	Total density (no. of plants/ sq. ft.)	Density of shadscale (no. of plants/ sq. ft.)	% of total basal cover	% of total canopy cover	% of shadscale in canopy cover	% of galleta grass in canopy cover
B2 horizon						
pH (paste)	-.062	-.134	.122	.135	.230	-.239
pH (1:5)	.433	.404	.284	.582	.225	-.085
Base exchange capacity (me. /100 g.)	.553	-.606	.369	.252	-.640	.728*
Exchangeable K (me. / 100 g.)	.362	-.551	.248	.117	-.660	.585
Exchangeable Na (me. / 100 g.)	.363	-.197	.056	.202	-.147	.216
Total soluble salts percentage	-.140	.164	-.388	-.282	.140	.038
Saturation extract conductivity (K x 10^3)	-.397	.374	-.517	-.393	.346	-.338
Moisture percentage at saturation	.008	-.186	-.040	.072	-.117	-.018
1/3 atmosphere moisture percentage	.484	-.275	.266	.388	-.366	.383
Lime percentage	.112	.560	.186	.481	.309	-.361

Table 21. Continued.

Soil factors for the different horizons	Total density (no. of plants/ sq. ft.)	Density of shadscale (no. of plants/ sq. ft.)	% of total basal cover	% of total canopy cover	% of shadscale in canopy cover	% of galleta grass in canopy cover
Lime horizon (Cca)						
pH (paste)	-.562	.540	-.494	-.435	.732*	-.546
pH (1:5)	-.400	.455	-.238	-.220	.649	-.517
Base exchange capacity (me. / 100 g.)	.135	-.298	.205	.148	-.303	.079
Exchangeable K (me. / 100 g.)	.207	-.239	.505	.402	-.291	.027
Exchangeable Na (me. / 100 g.)	-.511	.156	-.350	-.384	.400	-.536
Total soluble salts percentage	.420	-.669*	-.051	-.142	-.723*	.603
Saturation extract conductivity (K x 10^3)	.490	-.611	.007	-.049	.727*	.658
Moisture percentage at saturation	-.158	-.202	-.123	-.152	-.136	-.049
1/3 atmosphere moisture percentage	.434	.113	-.063	.209	.236	.157
Lime percentage	.039	.171	.040	275	.248	-.160

Table 21. Continued.

Soil factors for the different horizons	Total density (no. of plants/ sq. ft.)	Density of shadscale (no. of plants/ sq. ft.)	% of total basal cover	% of total canopy cover	% of shadscale in canopy cover	% of galleta grass in canopy cover
Gypsiferous horizon (Ccs)						
pH (paste)	-.263	.294	-.597	-.495	.308	-.081
pH (1:5)	-.374	.246	-.597	-.506	.503	-.235
Base exchange capacity (me./100 g.)	-.031	.066	.512	.414	-.165	-.207
Exchangeable K (me./ 100 g.)	.461	-.342	.600	.497	-.313	.193
Exchangeable Na (me./100 g.)	-.783*	.637	-.659	-.591	.639	-.688*
Total soluble salts percentage	-.020	-.032	.577	.447	-.284	-.107
Saturation extract conductivity (K x 10^3)	.136	-.443	.230	.121	-.663	.270
Moisture percentage at saturation	.131	.188	.475	.482	-.160	-.050
1/3 atmosphere moisture percentage	.166	.006	.468	.439	-.306	.050
Lime percentage	.163	.254	.603	.734*	.059	-.298

* r values greater than .666 are significant at .05 level.
** r values greater than .798 are significant at .01 level.

Table 22. Correlation coefficients between soil factors of three different horizons and the vegetation characteristics of the association of Atriplex nuttallii var. nuttallii-Hilaria jamesii.

Soil factors for the different horizons	Total density (no. of plants/ sq. ft.)	Density of saltbush (no. of plants/ sq. ft.)	% of total basal cover	% of total canopy cover	% of saltbush in canopy cover	% of galleta grass in canopy cover
Surface horizon (A1)						
pH (paste)	.204	-.027	.523	.295	.003	.262
pH (1:5)	-.453	-.639	.040	-.281	-.331	.270
Base exchange capacity (me./ 100 g.)	.116	.074	-.009	-.181	.050	.384
Exchangeable K (me./ 100 g.)	.100	-.009	.312	.181	.158	.139
Exchangeable Na (me./ 100 g.)	.281	-.011	.277	.046	-.151	.463
Total soluble salts percentage	.437	.537	.135	.223	.061	.110
Saturation extract conductivity (K x 10^3)	.380	.328	.017	.173	-.121	.071
Moisture percentage at saturation	.256	.513	.027	.147	.106	-.058
1/3 atmosphere moisture percentage	-.043	.536	.198	.262	.512	-.440
Lime percentage	-.573	.122	-.362	-.137	.600	-.902**

Table 22. Continued.

Soil factors for the different horizons	Total density (no. of plants/ sq. ft.)	Density of saltbush (no. of plants/ sq. ft.)	% of total basal cover	% of total canopy cover	% of saltbush in canopy cover	% of galleta grass in canopy cover
Gypsiferous horizon (Ccs)						
pH (paste)	.123	-.458	.234	.155	-.844**	.529
pH (1:5)	-.558	-.898**	-.050	-.111	-.664	.022
Base exchange capacity (me./ 100 g.)	.568	.798**	.628	.671*	.376	-.105
Exchangeable K (me./ 100 g.)	.719*	.397	.213	.424	-.408	.350
Exchangeable Na (me./ 100 g.)	-.407	-.185	-.473	-.610	.300	-.087
Total soluble salts percentage	.562	.547	.415	.410	.183	.190
Saturation extract conductivity (K x 10^3)	.603	.710*	.119	.096	.278	.230
Moisture percentage at saturation	.587	.581	.350	.437	-.271	.125
1/3 atmosphere moisture percentage	.489	.325	.583	.657	-.067	.139
Lime percentage	-.663	.086	-.305	-.137	.508	-.904**

Table 22. Continued.

Soil factors for the different horizons	Total density (no. of plants/ sq. ft.)	Density of saltbush (no. of plants/ sq. ft.)	% of total basal cover	% of total canopy cover	% of saltbush in canopy cover	% of galleta grass in canopy cover
Shale horizon (R)						
pH (paste)	-.090	-.397	.533	.578	-.597	-.056
pH (1:5)	-.315	-.430	.317	.325	-.516	-.164
Base exchange capacity (me./ 100 g.)	.552	.576	.387	.468	..243	.097
Exchangeable K (me./ 100 g.)	.156	.706*	.025	.369	.570	-.679*
Exchangeable Na (me./ 100 g.)	.085	-.302	.381	.444	-.543	-.023
Total soluble salts percentage	.078	-.198	.664	.738*	-.502	-.031
Saturation extract conductivity (K x 10^3)	.088	-.224	.461	.546	-.594	.080
Moisture percentage at saturation	.143	.024	.221	.279	.032	-.003
1/3 atmosphere moisture percentage	.237	.241	-.159	.063	.181	-.054
Lime percentage	-.177	.460	-.158	.318	.473	-.759*

* r values greater than .666 are significant at .05 level.

** r values greater than .798 are significant at .01 level.

Table 23. Correlation coefficients between the various soil factors of the three different horizons and the vegetational characteristics of the association of *Atriplex nuttallii* var. *gardneri*-*Aster xylorrhiza* .

Soil factors for the different horizons	Total density (no. of plants/ sq. ft.)	Density of saltsage (no. of plants/ sq. ft.)	% of total basal cover	% of total canopy cover	% of saltsage in canopy cover	% of woody aster in canopy cover
Surface horizon (A1)						
pH (paste)	.474	.279	.321	.388	-.323	-.075
pH (1:5)	.238	-.526	-.365	-.239	-.447	.445
Base exchange capacity (me./ 100 g.)	.626	-.254	.505	.593	-.424	-.135
Exchangeable K (me./ 100 g.)	.268	-.179	.543	.674*	-.268	-.475
Exchangeable Na (me./ 100 g.)	.196	-.239	.051	.176	-.231	-.225
Total soluble salts percentage	.227	-.266	.200	.300	.022	-.237
Saturation extract conductivity (K x 10^3)	.311	.338	.295	.217	.267	-.131
Moisture percentage at saturation	.275	.240	-.174	-.210	.793*	-.229
1/3 atmosphere moisture percentage	.241	.506	.240	.214	.633	-.689*
Lime percentage	-.373	.475	-.289	-.418	.634	-.162

Table 23. Continued.

Soil factors for the different horizons	Total density (no. of plants/ sq. ft.)	Density of saltsage (no. of plants/ sq. ft.)	% of total basal cover	% of total canopy cover	% of saltsage in canopy cover	% of woody aster in canopy cover
Shale horizon (R1)						
pH (paste)	.067	.148	-.429	-.398	-.090	.399
pH (1:5)	.280	-.350	-.172	-.041	-.329	.106
Base exchange capacity (me./ 100 g.)	.641	-.227	.552	.634	-.463	-.114
Exchangeable K (me./ 100 g.)	.046	-.265	.202	.329	.025	-.273
Exchangeable Na (me./ 100 g.)	.059	.274	.534	.468	.366	-.528
Total soluble salts	-.422	-.048	.234	.194	.609	-.305
Saturation extract conductivity (K x 10^3)	-.140	.277	-.174	-.307	.399	.112
Moisture percentage at saturation	-.364	-.409	-.184	-.062	-.244	-.024
1/3 atmosphere moisture percentage	.131	-.664	-.165	-.010	-.817**	.443
Lime percentage	-.379	.496	-.349	-.468	.750*	-.119

Table 23. Continued.

Soil factors for the different horizons	Total density (no. of plants/ sq. ft.)	Density of saltsage (no. of plants/ sq. ft.)	% of total basal cover	% of total canopy cover	% of saltsage in canopy cover	% of woody aster in canopy cover
Shale horizon (R2)						
pH (paste)	-.304	.017	-.416	-.535	.088	.296
pH (1:5)	-.268	-.465	-.113	-.129	-.114	.165
Base exchange capacity (me./ 100 g.)	.579	.130	.790*	.876**	-.231	-.563
Exchangeable K (me./ 100 g.)	.004	-.419	-.421	-.304	-.038	.427
Exchangeable Na (me./ 100 g.)	.437	.369	.571	.673*	-.442	-.336
Total soluble salts percentage	-.257	-.071	.260	.157	.378	-.271
Saturation extract conductivity (K x 10^3)	-.297	.047	.322	.179	.279	-.138
Moisture percentage at saturation	-.700*	-.515	-.259	-.295	.142	.093
1/3 atmosphere moisture percentage	-.512	-.201	-.020	-.126	.208	.099
Lime percentage	-.492	.276	-.488	-.608	.497	.081

* r values greater than .666 are significant at .05 level.
** r values greater than .798 are significant at .01 level.

Table 24. Correlation coefficients between the various soil factors of five different horizons and the vegetation characteristics of the community of *Atriplex corrugata*.

Soil factors for the different horizons	Total density (no. of plants/ sq. ft.)	Density of mat saltbush (no. of plants/ sq. ft.)	% of total basal cover	% of total canopy cover	% of mat saltbush in canopy cover
Surface horizon (A1)					
pH (paste)	.133	-.206	.845**	.808**	-.459
pH (1:5)	-.378	-.109	.224	.123	.241
Base exchange capacity (me./ 100 g.)	.083	.404	-.402	-.410	.086
Exchangeable K (me./ 100 g.)	-.077	.258	-.612	-.601	.058
Exchangeable Na (me./ 100 g.)	.054	.082	.727*	.648	-.072
Total soluble salts percentage	-.025	.092	.648	.574	.158
Saturation extract conductivity (K x 10^3)	-.085	.007	.614	.538	.076
Moisture percentage at saturation	.146	.090	.237	.212	.200
1/3 atmosphere moisture percentage	.104	.332	-.463	-.437	.082
Lime percentage	.077	.050	.355	.263	.104

Table 24. Continued.

Soil factors for the different horizons	Total density (no. of plants/ sq. ft.)	Density of mat saltbush (no. of plants/ sq. ft.)	% of total basal cover	% of total canopy cover	% of mat saltbush in canopy cover
Horizon (B2)					
pH (paste)	.001	-.411	.431	.390	-.620
pH (1:5)	-.367	-.108	.028	-.118	.023
Base exchange capacity (me./ 100 g.)	.261	.356	.012	.026	.081
Exchangeable K (me./ 100 g.)	.459	.585	.201	.191	-.037
Exchangeable Na (me./ 100 g.)	.206	-.070	.177	.159	-.372
Total soluble salts percentage	-.280	-.027	-.071	-.181	-.311
Saturation extract conductivity (K x 10^3)	-.138	-.146	-.243	-.209	-.233
Moisture percentage at saturation	.150	-.051	.205	.182	-.024
1/3 atmosphere moisture percentage	.013	-.178	-.271	-.146	.044
Lime percentage	-.228	.039	.005	-.102	.258

Table 24. Continued.

Soil factors for the different horizons	Total density (no. of plants/ sq. ft.)	Density of mat saltbush (no. of plants/ sq. ft.)	% of total basal cover	% of total canopy cover	% of mat saltbush in canopy cover
Buried horizon (A1.b)					
pH (paste)	.005	.079	.415	.324	-.079
pH (1:5)	-.535	-.296	.155	.047	.487
Base exchange capacity (me./ 100 g.)	.183	-.098	-.225	-.123	-.132
Exchangeable K (me./ 100 g.)	-.270	.249	-.593	-.596	.576
Exchangeable Na (me./ 100 g.)	-.126	.027	.030	-.001	.310
Total soluble salts percentage	-.351	-.256	.509	.376	-.216
Saturation extract conductivity (K x 10^3)	-.190	.030	.469	.390	.099
Moisture percentage at saturation	.539	-.131	.495	.571	-.373
1/3 atmosphere moisture percentage	.430	.246	-.255	-.107	-.086
Lime percentage	-.103	.116	.286	.154	.299

Table 24. Continued.

Soil factors for the different horizons	Total density (no. of plants/ sq. ft.)	Density of mat saltbush (no. of plants/ sq. ft.)	% of total basal cover	% of total canopy cover	% of mat saltbush in canopy cover
Salt layer (Csa)					
pH (paste)	-.366	-.472	.169	.112	-.165
pH (1:5)	-.719*	.118	-.627	-.743*	.563
Base exchange capacity (me./ 100 g.)	.615	.642	-.197	-.098	.256
Exchangeable K (me./ 100 g.)	.058	.362	-.553	-.503	.593
Exchangeable Na (me./ 100 g.)	.110	.448	-.622	-.599	.171
Total soluble salts percentage	-.130	.343	.498	.409	-.265
Saturation extract conductivity ($K \times 10^3$)	-.078	-.122	.313	.204	-.572
Moisture percentage at saturation	.445	-.059	.424	.539	.061
1/3 atmosphere moisture percentage	.355	-.104	.140	.187	-.848**
Lime percentage	-.717*	-.256	-.181	-.306	.161

Table 24. Continued.

Soil factors for the different horizons	Total density (no. of plants/ sq. ft.)	Density of mat saltbush (no. of plants/ sq. ft.)	% of total basal cover	% of total canopy cover	% of mat saltbush in canopy cover
Shale horizon (R)					
pH (paste)	.224	-.036	.702*	.672*	.070
pH (1:5)	-.133	-.140	.379	.321	.520
Base exchange capacity (me./ 100 g.)	.364	.322	-.253	-.160	.136
Exchangeable K (me./ 100 g.)	-.384	-.098	-.363	-.381	.004
Exchangeable Na (me./ 100 g.)	.216	.331	.064	.054	.470
Total soluble salts percentage	.224	.172	.568	.545	.183
Saturation extract conductivity (K x 10^3)	.031	.313	.142	.053	.497
Moisture percentage at saturation	.638	-.103	.332	.499	-.433
1/3 atmosphere moisture percentage	.294	.223	-.475	-.326	022
Lime percentage	-.234	.005	.004	-.071	-.005

* r values greater than .666 are significant at .05 level.
** r values greater than .798 are significant at .01 level.