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VEGETATION of FORT BLISS

TEXAS and NEW MEXICO

FINAL REPORT

VOLUME II

VEGETATION MAP

Submitted to

Directorate of Environment, Cultural/Natural Resources Division
Fort Bliss Military Reservation
Fort Bliss, Texas 79916-0058

ATTN: Kevin von Finger

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Kevin von Finger
Directorate Of Environment
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Dear Kevin,

It is my pleasure to deliver the final report "Vegetation of Fort Bliss, Texas and New Mexico, Volume II: Vegetation Map." You will find enclosed five copies of the report; only the first copy has maps contained in a map pocket in the back of the report. You should have also received in a separate mailing, un-folded copies of the maps. I have also sent along an unbound version of the report for copy purposes. The 1:120,000 map is in its final form, but we have produced only few draft hard copies of the 1:50,000 maps. We appreciate comments on the map before we produce the remainder of the 1:50,000 map sheets in hard copy form as part of a Supplement to this report (which will include an index map and a final map accuracy assessment).

Sincerely,

Dr. Esteban Muldavin
Co-Principal Invesitigator

Table of Contents

Introduction

This volume details the development of a vegetation map based on satellite imagery for Fort Bliss, Texas and New Mexico. The map presented here was developed concurrently with a vegetation classification for the Fort (Volume I). The map and classification together form part of the biological baseline for NEPA and Endangered Species Act compliance, and will help meet inventory and classification requirements for natural resources management on US Army installations (AR 200-3 sections 2-2, 3-3 and 11-3).

The map has been designed to be complementary to the vegetation classification of Volume I. While the vegetation classification describes the composition and habitats of vegetation communities of the Fort along with ecological and management interpretations, the map provides an explicit depiction of these communities in the landscape. Map units are directly linked to the vegetation community descriptions in Volume I, resulting in a map which maximizes ecological information content.

The map is presented in both paper and digital forms. In its digital form, the map and its associated spatial/spectral statistics and biological database information can be directly input into the installation Geographical Information System (GIS) and used in various natural resources management applications.

Study Area

Location

The study area is Fort Bliss, the U.S. Army Air Defense Artillery Center, which lies roughly between 105° and 107° longitude and 31°30' and 33° latitude (Figure 1). Elevation ranges between 1,350 m (3,900 ft.) in the Tularosa Basin floor to over 3,100 m (9,000 ft.) at the top of the Organ Mountains. Fort Bliss comprises approximately 1.1 million acres and is largely within Otero County, New Mexico with smaller portions in Doña Ana County, New Mexico as well as El Paso and Hudspeth Counties, Texas. Highway 54 passes through the center of the Fort connecting Alamogordo, New Mexico and El Paso, Texas. The town of Orogrande lies halfway between Alamogordo and El Paso, at the base of the Jarilla Mountains. White Sands Missile Range lies along the northern boundary and the Lincoln National Forest and Bureau of Land Management abut it on the east and west sides.

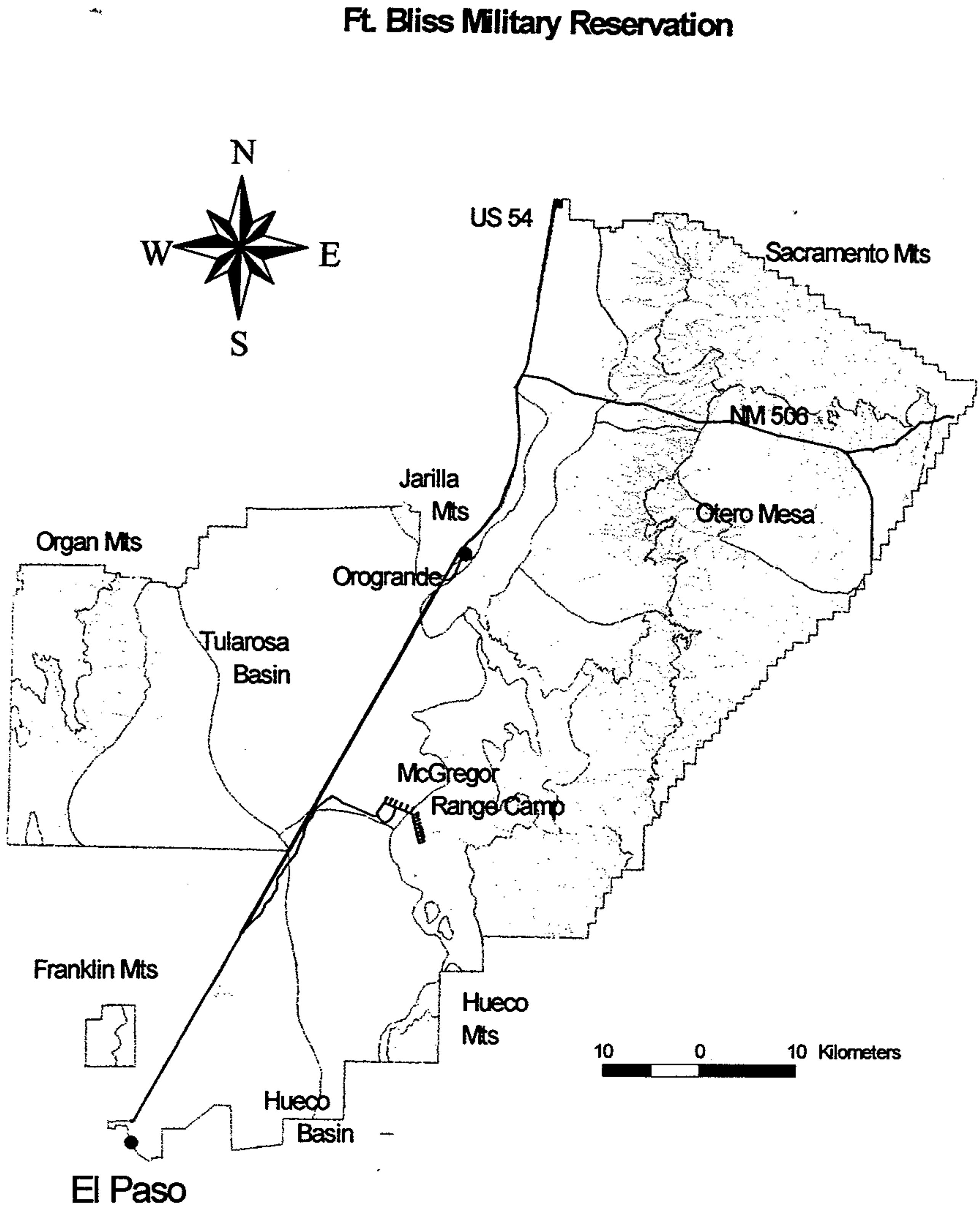

Figure 1. Study area. All areas within the Fort Bliss Military Reservation were mapped except for small isolated holdings in the Franklin Mountains and cantonment areas.

Climate

Fort Bliss is located in a semi-arid region within the northern portion of the Chihuahuan Desert as delineated by Schmidt (1986). The two meteorological stations used by the Fort are located on the basin floor. The station in the southern part of the range is at the El Paso International Airport. The other station lies just across the northern boundary at White Sands 'C' Site, New Mexico. There is no data recorded for the higher parts of the range such as the Organ and Sacramento Mountains and Otero Mesa. Several unmanned meteorological stations which measure wind speed and direction, temperature, precipitation, and particle movement are currently being installed on the base, but no data is as yet available (Russell 1996, personal communication).

Precipitation is probably the most important climatological factor for vegetation in this area where maximum temperatures of over 32.2°C (90°F) are exceeded for approximately 105 days out of the year. The mean annual precipitation is 225 mm (8.5 inches). The summer months, June through August, receive 73% of the maximum temperatures and 39% of the annual precipitation.

The seasonal fluctuation of precipitation is a result of prevailing wind directions which can bring in the frontal storms from the north or the Pacific or Caribbean cyclonal systems. Overall prevailing wind direction is from the west and dominates the area from February to June. October through January winds are from the north, and during the months of July through September the prevailing winds are south to southeasterly. The orographic effects of the surrounding north-south ranges further aid in the dissipating effects on rainstorms.

Climate data was compiled for two sites near Fort Bliss and compared to Schmidt's (1986) averages for the Chihuahuan Desert. The average temperature and precipitation from the North American sites correspond well with the Schmidt (1986) data (Table 1). Using the de Martonne Index of Aridity (de Martonne, 1926)[1], both the El Paso and White Sands meteorological sites would be classified as 'Dry Steppes', according to Schmidt (1979). An index of less than or equal to 10 was used by Schmidt to delineate the Chihuahuan Desert. An aridity value below 5 is considered to be a true desert. The El Paso site alone has an aridity index of 7.67 and the White Sands site has one of 12.5. The average of the El Paso and White Sands sites was used to calculate an overall aridity index of 10.07. Since the Fort primarily falls within these two sites, the average is the most appropriate to use in the calculation for the index.

[1] See Chapter 2.1 Chihuahuan Desert for a detailed discussion on the de Martonne Index of Aridity.

Table 1. Climate data for the Chihuahuan Desert (Schmidt, 1986) and two meteorological stations near Fort Bliss. El Paso International Airport data is for the years 1948-1990. White Sands Missile Range 'C' Site is for the years 1980-1991.

Site	Temp °C Annual Min Max Avg	Precip (mm) Average	Wind Prev	Snowfall (mm)
Chihuahuan	14-23[2]	235	n/a	n/a
El Paso	9.9 25.9 17.7	212.5	w	150
White Sands	7.7 24.9 16.6	334.5	w (170-190)	280

Landscape

Fort Bliss lies within the Basin and Range Province, the majority of which falls within the Mexican Highland Section and the eastern part designated as the Sacramento Section (Williams, 1986). The major features of the landscape are the internally drained Tularosa and Hueco Basins which stretch down through the central portion of the Fort. At the northern portion of the study area, the Tularosa Basin spans a distance of over 65 km (40 miles) between the Organ Mountains to the west and the southern Sacramento Mountains and Otero Mesa to the east. It then narrows southward between the Franklin Mountains on the west and the Hueco Mountains to the east. It is at this point, near the New Mexico/Texas border that a "low, indefinite transverse divide" separates the Tularosa to the north from the Hueco Basin to the south (Knowles and Kennedy, 1956) Both basins are west-dipping grabens which gradually rise to the east. They generally contain unconsolidated Quaternary fill deposits composed of granitic, porphyritic and sedimentary (limestone and sandstone) rocks.

The geology of the Organs is complex and has been mapped in detail by Seager (1981). The Organ Mountains are essentially an island of igneous intrusive and extrusive rocks amongst predominantly sedimentary mountain ranges, and basins filled with Holocene sediments. Generally, the rocks in the northern and eastern portions of the area are composed of intrusive quartz monzonite, granite and diorite associated with the middle Tertiary Organ Batholith. To the south and west, the rocks are dominated by extrusive rhyolite, tuff and andesite associated with middle Tertiary volcanism. Older sedimentary rocks of sandstone, limestone and shales can occur, but their exposures are relatively minor, both in comparison to the surrounding igneous rocks and with respect to the adjacent predominantly sedimentary

[2]Schmidt (1986) states 3-4°C should be added to the average temperature for the northern portions of the Chihuahuan.

mountain ranges of the Franklin's to the south and the San Andres to the north. Late Pleistocene and Holocene alluvial deposits occur in mountain valley bottoms and as extensive alluvial fans and piedmonts plains discharged from mountain valleys out into the adjacent basins.

The Franklin Mountains are to the south of the Organs, and run nearly north-south, straddling the New Mexico/Texas border. The range resembles a typical Basin and Range fault-block mountain which dips to the west and has a steep escarpment to the east. Pre-Cambrian granitic rocks are exposed along the escarpment base and are overlain by numerous layers of sedimentary limestone and sandstone.

On the east side and to the north in the study area lie the foothills of the southern end of Sacramento Mountains. The Sacramentos are also a tilted fault block range with a steep west-facing escarpment composed of sedimentary limestones and sandstones overlaying the granitic basement rocks. Otero Mesa lies directly to the south of the Sacramento Mountains, and is a gently sloping sedimentary plateau with an average elevation of 1,800 m (6,000 ft). It too has a steep escarpment that faces west out into the Tularosa basin. Overlain on the basement Pre-Cambrian granitics are primarily limestones and sandstones of the Abo-Hueco Formation. Along the ridge of the mesa on the west face is a narrow band of a red sandstone member of the Yeso Formation. From the top of Otero Mesa, continuing in a gentle slope to the east are primarily limestone members of the Yeso Formation. Further to the south are the Hueco Mountains, also primarily a sedimentary fault-block range dominated by the Abo-Hueco sandstones, but with volcanic intrusions. The Jarilla Mountains are a small, intrusive volcanic range which puncutate the Tularosa Basin floor at the north-central boundary of the study area.

The geomorphology of the study area is complex. At the base of the mountains and escarpments are extensive alluvial fans and piedmont slopes extending out into the basin floors. The major landforms on the Fort associated with the piedmont slope, are mountain-valley fans, ballenas, and alluvial fan. The major landforms associated with the basin floor are alluvial flats, alluvial plain, sand sheet, coppice dunelands, sand dunes, and playa.

Mountain valley fans occur in intra-montane basins or wide mountain valleys. The fans often coalesce near the backslope position and meet an axial drainage system which tends to abruptly truncate the fans. These are generally considered erosional surfaces. Cyclical erosions of materials principally from the backslope of the mountain front or relict fan are carried to progressively lower positions on the fan. An example of this is the mountain valley fans extending from the southern reaches of the Organ Mountains. Rattlesnake Ridge is the source of the eastern border of this intra-montane valley.

Ballenas occur along some mountain fronts and are ridgeline remnants of fan alluvium with distinct, broadly rounded surfaces. The ballenas are often located on the upper piedmont slope, but can also be located at the margins of fan piedmonts. Examples of these are found at the southern end of the Sacramento Mountains and the western ridge of Otero Mesa. They have well developed Pleistocene soils which are remarkably uniform on all positions (i.e. backslope, sideslope, ridge) and represent a late stage of piedmont dissection (Gile and Grossman 1979). The well developed Pleistocene soils have either clayey argillic horizons, indurated duripans, or petrocalcic horizons. Some of the younger ballenas located at the margins of the piedmont may have been subjected to Holocene erosional processes which alter the soil profile. Many of these surfaces are covered with grama grasses and sacahuista.

The alluvial fans are the more common expressions of alluviated material in the piedmont. Most of these semi-conical shaped fans, which run parallel to the mountain front, are deeply incised by drainages. Lateral joining of the fans makes up the fan piedmont or bajada. The alluvium is well sorted and typically has coarser textured material in the upper portion of the fan with finer textured deposits on the toeslopes. However, some rocks are more resistive than others, depending upon the source material. Granite, sandstone, and limestone are the main contributors. The more resistive rocks such as granite have fine-gravelly or coarse-sandy fans, these are predominant on the eastern face of the Organ Mountains. Limestones form fans which tend to be more gravelly. Aluvium grades from stoney the apices of the fans to loamy textures moving downslope. These fans occur along all the uplifts on the eastern side of the Fort as well as along the western face of Rattlesnake Ridge in the Organ Mountains. Volcanic material forms angular-stoney and very gravelly fans. The volcanics are limited to the Jarilla Piedmont.

The drainages occurring on the fan and between the fans (inset fans) continually modify the environment by creating new fans at the mouth of the drainages. The younger fans are the inset fans created by ephemeral streams which lie between older fan remnants. Many of these can be seen near the basin floor at the mouths of large drainages from Otero Mesa, such as Rough Canyon. These fans are crudely sorted and are dissected by gullies. The material in the drainages may be from various fans of different origins and different degrees of soil development. They often have a complex of gravelly surficial material with discontinuous areas of swales bounded by gravelly alluvium and gullies.

Alluvial flats occur extensively within the basin floor. They commonly extend from the base or edge of the alluvial piedmont (bajada) or fans out to the axial stream floodplain of the basin or to a playa. The source material for the alluvial flats is usually from the surrounding raised surfaces of the basin. Eolian and lacustrine deposits may cover portions of the alluvial flat (Hawley, 1980). These nearly flat surfaces are subject to sheet erosional processes which run parallel to the basin axis.

Alluvial plains are sediments deposited by streams or stream deltas whose origins are great distances from the basin. The ancestral Rio Grande flowed into the Tularosa Basin leaving its well-sorted stream sediments within the study area. These alluvial plain sediments are referred to as the Camp Rice Formation. Some of these sediments are the source material for the dunes within the basin floor. These sediments may underlie the extensive dunelands within the basin.

Sand sheets, coppice dunes, and sand dunes are derived from the sands of playas which are barren expressions of the bottoms of the ancestral lakes. Large quantities of sand were available when these lacustrine environments dried up and winds carried the sands to surrounding areas, often depositing them onto the surrounding piedmont surfaces and even over some of the lower mountains. Sands have been deposited onto Otero Mesa and large dunes have developed in some of the inter-mountain valleys at the base of the Sacramento Mountains. The piedmont of Otero Mesa is a mosaic of primarily alluviated material with discontinuous areas of sand sheets. The basin floor is dominated by coppicing dunes (dunes forming around and stabilized by honey mesquite shrubs) and some elongated sand dunes. These are highly permeable sands which have distinct vegetation associates in the basin. A complex of soil micro environments exist within on-dune and inter-dune positions and can affect plant distribution.

Playas are areas located within the basin floor, typically barren and ephemerally flooded. Such areas can have a thin veneer of non-gravelly, fine textured sediments. Most of these playas are the remains of pluvial lake bottoms with Holocene deposits covering the old pluvial lacustrine sediments. The Holocene deposits are silt loam or silty clay and the old lake beds are clays. Topographically low areas, located at the base of the alluvial flats and some piedmont slopes, also have some of the characteristics of these larger playas.

Vegetation

The vegetation of the study area is diverse, ranging from Chihuahuan Desert Scrub in the basin bottoms to Rocky Mountain conifer forest on the mountain tops. Detailed descriptions of the major vegetation communities of the Fort are provided in Volume I with a general summary below.

In the Organ Mountains, vegetation zones follow a definite elevation gradient. Desert shrublands and grasslands dominate the lower elevations foothills and alluvial fan piedmonts. At middle elevations, conifer and evergreen oak woodlands, along with mountain scrub and chaparral cover the hillslopes. At the highest elevations ponderosa pine and Douglas-fir forest predominate along with deciduous oak woodlands and montane grasslands. Drainage ways contain significant riparian forest and shrubland vegetation, particularly where water is perennially present. (DeOlivera, 1961; Dick-Peddie, 1993; Dick-Peddie and Moir 1970; Moir, 1963).

The foothills of the Sacramento Mountains and the top of Otero Mesa generally support plains and desert grasslands dominated by blue, black, hairy and sideoats gramas and New Mexico needlegrass. Yuccas are commonly conspicuous along with numerous sub-shrubs.

The alluvial fans and piedmonts support a diversity of desert shrub and grassland communities. Common dominants are creosotebush, acacia, money mesquite and lechuguilla along with grasses such as black grama, sideoats grama, and bush muhly.

The basin floors are characterized by extensive shrublands dominated by honey mesquite, creosotebush and occasionally sandsage, with scattered, small patches of grassland dominated by mesa dropseed, tobosagrass and sacaton.

Materials and Methods

Mapping Strategy

In order to develop a map which accurately depicts patterns of vegetation over this desert landscape a strategy was used that combines ecological field studies and remote sensing imagery in the context of a GIS (Figure 2). The first step was the acquisition and processing of Landsat Thematic Mapper (TM) imagery over the study area. A preliminary analysis was then run to determine optimal strategies for mapping and field sampling. Based on this analysis, an additional TM satellite image was acquired to enhance the image analysis (multi-temporal analysis of vegetation signatures). The images were then processed to account for geometric and radiometric distortions of the raw imagery.

The preliminary analysis also indicated a need to stratify the image analysis by broadly defined landscape level elements to overcome disparate, but localized misclassifications that occurred across the image. Thus, ancillary data layers such as soils and geology maps along with anecdotal biological information and the TM imagery itself were used to define landscape units and to develop a landscape unit map.

A supervised image classification was then performed within each landscape unit based on selected classified vegetation data gathered by the ground vegetation survey. Details of how this data was gathered and classified into vegetation types are provided in Volume I. The various landscape unit analyses were then combined into a preliminary vegetation map for the Fort where each map class is represented by a particular ground point, which in turn is defined in terms of community types of the vegetation classification.

Individual map classes were then combined into final map units based on vegetation composition, spatial continuity and similar landscape structure, and then the final vegetation map generated. The final map units are described in general terms and linked to the vegetation community descriptions (Community Characterization Abstracts) of the Vegetation Classification. The final map was then accuracy tested using independent, ground and airborne videography data.

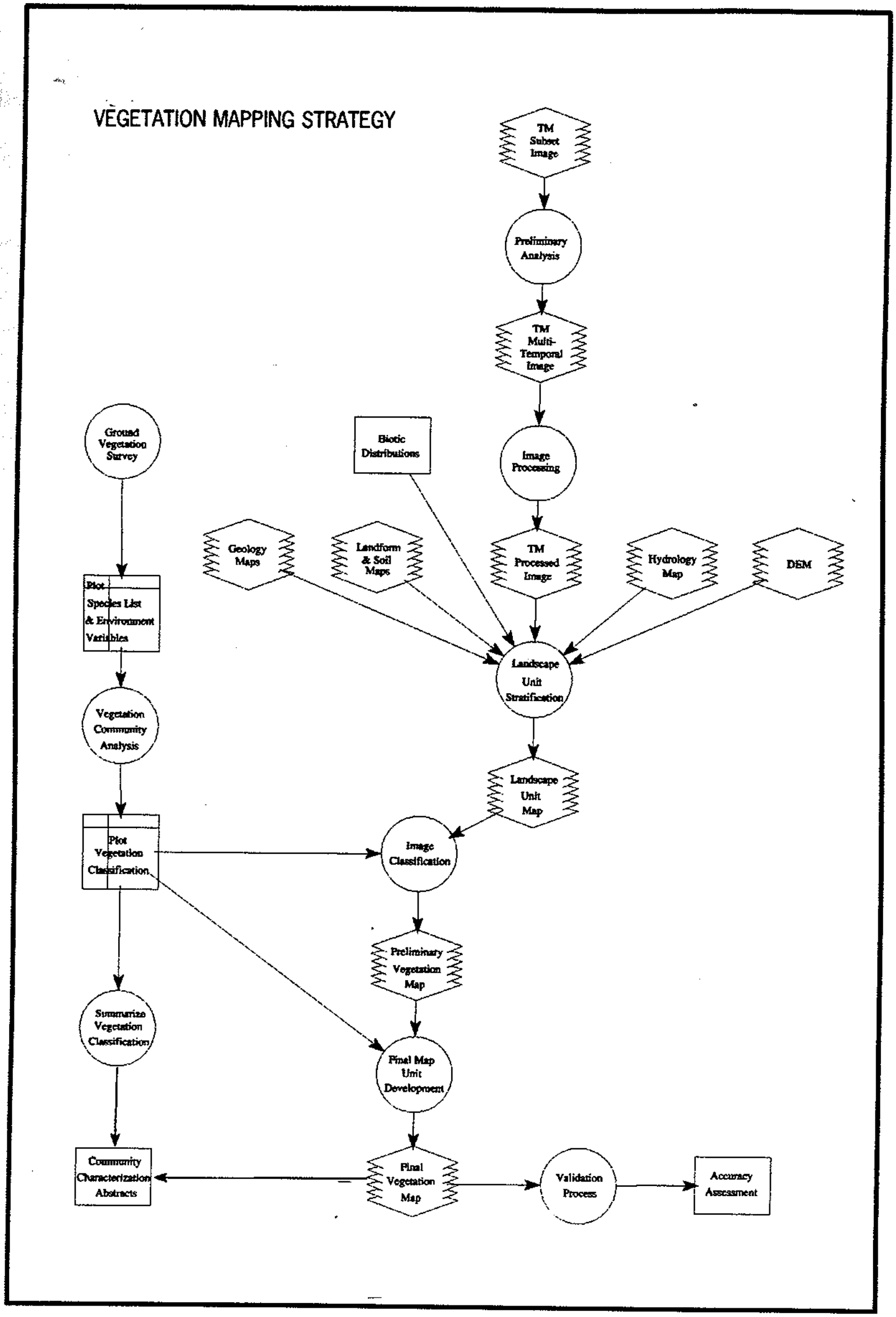

Figure 2. Flow chart detailing the mapping strategy used to develop the Fort Bliss Vegetation Map.

Data Sources

Satellite Imagery

Landsat Thematic Mapper (TM) satellite imagery was selected for mapping the natural vegetation cover for the study area. TM imagery was chosen over aerial photography for a variety of reasons. The cost per square mile for satellite data is less than that for aerial photography both in terms of direct costs and in the ensuing map development. It takes only one full scene and an additional sub-scene to cover the study area, and imagery comes in a digital form suitable for analytical and computerized map production. Satellite imagery, with its stable sensor platform, is relatively easy to geometrically correct to known coordinates of a base map, thus avoiding the complex geometry of orthorectifying and mosaicking hundreds of aerial photos. Further, the height of the sensor above the Earth (705 km. for Landsat) negates most parallax problems which are associated with aerial photography (parallax is the apparent change in positions of stationary objects affected by the viewing angle -- creating greater distortions at greater distances from the center of a aerial photo). Also, satellite data do not have the radiometric problems of air photos, such as hot spots, dark edges, and different contrasts for each photo due to sun-angle changes during the overflight.

The quantitative spectral and spatial aspects of TM imagery add particularly important dimensions to the mapping process. Multi-spectral satellite imagery records the variable reflection of natural radiation of surface materials such as rocks, plants, soils, and water. These groups have different chemical compositions so that incident radiation will react differently. Variations in plant reflection and absorption due to biochemical composition will register distinct spectral 'signatures' (Wickland 1991, Lillesand and Kiefer 1987). These signatures provide a quantitative measure of reflectance of specific wavelengths which can then be statistically analyzed to develop a vegetation map of spectrally similar plant communities.

Landsat TM has the highest spectral discrimination, with six spectral bands and one thermal band, among commercially available space-based sensors. Each band represents a specific range of light wavelength. For vegetation mapping, bands 2, 3, 4, and 5 are particularly useful. TM bands 3, 5 and 7 are useful for detecting variations in surface geology. Surface geology and soil discrimination are important to developing mapping units of the vegetation communities in sparsely vegetated areas that commonly occur on the Fort. Table 2 summarizes the function of each band.

TM integrates the spectral characteristics of each band over the Instantaneous Field of View (IFOV) of an area of 28.5m x 28.5m; this is the smallest area resolvable by the sensor and is represented on the computer screen by individual "pixels" (picture elements). Individual occurrences of plants are not resolved by the sensor; therefore, TM is particularly suited for evaluating and quantitatively identifying more generalized vegetation "community" occurrence patterns and their associated surface substrate characteristics.

Table 2. Landsat Thematic Mapper bands, their spectral ranges, and principal remote sensing applications for earth research (derived from Lillesand and Kiefer 1987).

Band	Wavelength (microns)	Spectral location	Principal applications
1	0.45-0.52	Blue	Designed for water body penetration, making it useful for coastal water mapping. Also useful for soil/vegetation discrimination, forest type mapping, and cultural feature identification.
2	0.52-0.60	Green	Designed to measure green reflectance peak of vegetation for vegetation discrimination and vigor assessment. Also useful for cultural feature identification.
3	0.63-0.69	Red	Designed to sense in a chlorophyll absorption region aiding in plant species differentiation. Also useful for cultural feature identification.
4	0.76-0.90	Near-infrared	Useful for determining vegetation types, vigor, and biomass content, for delineating water bodies, and for soil moisture discrimination.
5	1.55-1.75	Mid-infrared	Indicative of vegetation moisture content and soil moisture. Also useful for differentiation of snow from clouds.
6	10.4-12.5	Thermal infrared	Useful in vegetation stress analysis, soil moisture discrimination, and thermal mapping applications.
7	2.08-2.35	Mid-infrared	Useful for discrimination of mineral and rock types. Also sensitive to vegetation moisture content.

There are constraints to using TM imagery. Some of the principal problems occur when vegetation is not the major cover type and differential reflectances of various geologic substrates dominate. Topographic effects creating shadows within narrow valleys and steep scarps can also cause problems. A proper combination of field sampling and image processing techniques helps to alleviate most problems. Furthermore, the sensor cannot penetrate clouds or snow, but other TM images covering the same area free of clouds or snow can be acquired to fill these "gaps" in coverage. Finally, because of edge effects among a small number of spatially contiguous pixels, small occurrences of vegetation types are difficult to reliably map. Hence the minimum mapping unit polygon size is normally 0.5 ha or larger.

Other digital imagery was considered. French SPOT imagery, acquired by the Fort for another project, was rejected because of low spectral resolution (black and white), poor seasonality (winter), and the cost of analysis of higher spatial resolution data (10 m resolution of Spot significantly increases data storage and processing times). Similarly, low altitude aerial sensor data flown by jet by NASA for Fort Bliss were also evaluated, and although this data had high spectral and spatial resolution, it too suffered from poor seasonality, geometric distortion and incomplete coverage. Russian high resolution digital satellite photographs were also reviewed, but these images were very expensive and had extensive geometric distortion.

TM satellite images were purchased directly from Earth Observation Satellite Company (EOSAT) and are archived at Earth Data Analysis Center at the University of New Mexico. EOSAT is a private corporation that offers Landsat TM data on a scene basis covering a 185 km x 185 km area, with repetitive coverage over the same scene area every 16 days. See Appendix A for image specifications and dates.

Terrain Models

United States Geological Survey (USGS) Digital Elevation Models (DEMs) at 1:24,000 scale were purchased and mosaicked to provide digital elevation coverage for the study area. The DEMs were further processed to create slope and aspect images (Appendix A, raster images). A digital line coverage representing 80-foot contour intervals was developed from the raster DEMs using Arc/Info (Appendix A, vector coverages).

Ancillary Map Coverages

USGS Digital Line Graphs (DLGs) of road and drainage networks were downloaded from the USGS internet site and were compiled for the study area in Arc/Info.

The Fort Bliss GIS library files (GRASS format) were imported into both the ERDAS Imagine and Arc/Info format. Some of the files used for reference were the soils, landform, grazing units, and playa coverages.

The two soil coverages imported from the library had considerable east shift and attempts were made to re-register the data to fit the image data. Results were unsatisfactory, therefore the coverages could only be used as a reference.

Aerial Photography

Fort Bliss placed on loan to us their PIC photography with acetate overlays which delineated major vegetation cover, but the mosaics were not ortho-rectified. This made determining specific and precise locations difficult, particularly in areas of low topographic relief. Color-IR film positives associated with the NASA low altitude sensor data described above provided coverage for most of the study area and were used as references in accuracy checking of the image analyses. High altitude Color-IR photographs over the Organ Mountains were also used where possible.

Biological Data

The mapping process was dependent on ground survey vegetation data gathered by the NMNHP on Fort Bliss since 1990. This data resides in the NMNHP Biological and Conservation Database on a Microsoft Access platform and was exported to image processing software as needed. There are 750 field plots plus an additional 750 airborne videography derived validation points in the database. This ground data was subjected to extensive quality control as described in Volume I. A point coverage of selected field plots was developed in ERDAS and ARC-INFO and attributed with selected plot characteristics, such as species abundance values and percent surface soil, gravel, and rock cover, as well as vegetation type to according to the NMNHP vegetation classification (Appendix A, vector point coverage)

Preliminary Analysis

Prior to field work and extensive map development a preliminary analysis was performed to determine the optimal vegetation mapping procedure. Two limited test areas were selected from the TM imagery to evaluate various techniques: (1) parts of Otero Mesa, the mesa scarp, and the alluvial fan piedmont extending below the mesa to the west, and (2) Organ Mountains north of Soledad Canyon. Data previously collected by NMNHP in these areas from 1990-1993 were used to generate both the vegetation map and a map validation set for testing purposes.

Vegetation Indices

Two vegetation indices that are function of TM Bands 3 and 4 were compared for the best vegetation discrimination: the Normalized Difference Vegetation Index (NDVI) and the Soil Adjusted Vegetation Index (SAVI) (Huete et al. 1992). Both indices have been used in previous studies as indicators of vegetation. These indices enhance the difference in the chlorophyll absorption feature of TM3 and the peak vegetation response in TM4.

The NDVI for TM imagery is calculated as:

$$(TM4-TM3)/(TM4+TM3) \qquad \textit{(Eq. 1)}$$

The NDVI has repeatedly been shown to have high correlations with green biomass (Huete and Jackson 1987, Lauver and Whistler, 1993) and it tends to normalize the effects of differential illumination, shadowing, and soil color (Franklin *et al.* 1993).

The SAVI was of particular interest since it includes a correction factor for the soil background response of reflected radiation. SAVI for TM imagery is:

$$((TM4-TM3)/(TM4+TM3+L))*(1+L) \qquad \textit{(Eq. 2)}$$

where L= the correction factor used to minimize the secondary back-scattering effect of canopy transmitted-soil background reflected radiation. An L value of 1 was used here and is considered optimal in semiarid environments (Huete et al. 1992).

A difference image (Eq. 3) was created to identify differences between the two indices in order to select the one which performed the best. The difference image was created by subtracting the two images and displaying the results.

$$DIFF = (SAVI-NDVI) \qquad \textit{(Equation 3)}$$

The NDVI and SAVI difference image was designed so that high positive values indicated where there was a stronger response for the SAVI over the NDVI; high negative values would show just the opposite and values close to zero showed where they were the same.

Stepwise Discriminant Analysis of Band Combinations

A stepwise discriminant analysis procedure was performed to determine which combination of TM bands was most effective in differentiating vegetation pattern. Thematic Mapper bands 1, 2, 5, 6, 7, and the Normalized Difference Vegetation Index (NDVI) were evaluated and used in the selection process. TM bands 3 and 4 were not used since they are incorporated in the NDVI calculation, and hence considered as redundant. Mean spectral values were generated from the satellite imagery based on the 1990-1993 field data point locations and were used in the stepwise procedure along with their associated vegetation attributes.

Evaluation of Different Image Processing Techniques

Three different images representing various band combinations and ratios were created in order to determine which technique provided the best classification results. All of these images were classified with the same data. The resulting classifications were then tested against a field validation set.

The first analysis was performed on the combination of TM bands 1, 2, 5, and 7 with the exception of TM6 and the NDVI. Bands TM3 and TM4 were not used individually since they were used in the calculation of the NDVI. TM6 (thermal) was dropped from the analysis because it may contribute a disproportionate share of the weight for determining class membership due to its reduced dynamic range. This band also has a spatial resolution of

120m x 120m compared to the 28.5 m x 28.5 m resolution of the other bands; a difference that may affect classification accuracy.

The second analysis was performed on a composite of band ratioed images. Three ratios were used: TM4/TM3; TM4/TM5; and TM5/TM7. The ratio TM4/TM3 was used to enhance the subtle spectral variations in the scene for vegetation. Green biomass has a high reflective response in the near infra-red TM4 to the absorption feature response of TM3, the visible red. The ratio TM4/TM5 was similarly used to detect differences the community structure of vegetation (Cohen and Spies 1992). Though this ratio is less well understood, it has been used in forest studies. The ratio TM5/TM7 was also used to enhance the variation in vegetation by detecting differences in leaf structure. Greater absorption takes place in the middle infra-red TM7 than for the middle infra-red TM5 for plants and leaves which hold more water in their tissues (Lillesand and Kiefer 1987, Cohen and Spies 1992).

A third analysis was performed on all reflective bands of the TM image using Principal Components Analysis (PCA). PCA is a technique used to remove or reduce the redundancy in multispectral data (Lillesand and Kiefer, 1987). Additionally, it can be used to remove "noise" inherent in each band due to radiometric distortions. The procedure uses the original data set, in this case all reflective TM bands, and transforms the data into new channels or "components." These components are then used in the classification procedure. The first five components were used in the classification, with the sixth component excluded because it contained mostly random image "noise."

An independent set of field data points was used to evaluate the various classified images resulting from the analysis. For each point, a 40-meter distance buffer was established around each validation point to evaluate the accuracy of the image classifications. A contingency table of observed frequencies was used to calculate the percent correct for each classification.

Discriminant Analysis Models of Vegetation Types

A discriminant analysis procedure was used to derive a new set of image bands using the spectral means of sets of pixels representing specific vegetation community types (1993 Otero Mesa mapping project field points were used). Conceptally, discriminant function analysis should optimize for discrimnating among spectral groups as defined by vegetation type. Six discriminant functions were derived and applied in an image classification.

Image Processing

Acquisition and Mosaicking of the Multi-temporal Images

Spectral overlap can be a problem, particularly with respect to vegetation types. Typically, images are acquired at the peak 'green up' for vegetation mapping purposes. There can be considerable statistical overlap between vegetation types based solely on greenness at a particular point in time. The multi-temporal aspect of TM imagery can be taken advantage of to enhance differentiation of vegetation throughout the growing season. Specifically, a winter image was acquired in conjunction with the summer scene to help to spectrally separate deciduous from evergreen dominated vegetation types.

Two full scene satellite images and two quarter scenes were acquired to cover the study area (Appendix A). The summer quarter scene was used to fill a gap in coverage located in the northeast portion of the Fort of the full summer scene. The winter quarter scene was used to replace the snow capped region over the Organ Mountains. Histogram equalization adjustments were made to the images to account for the different illumination effects caused by sun angle for different days and years. The adjustments were applied to the quarter scenes using multiple regression equations and mosaicked to their respective full scenes.

Geometric Corrections

The images were map rectified using a nearest neighbor interpolation. This process makes the image planimetric so that area, direction, and distance measurements can be performed. The image-to-map rectification process involves selecting a point on the map with its coordinate and the same point on the image with its x and y coordinate. The root mean square error (RMS_{error}) is computed to determine how well the map and image coordinates fit in a least-squares regression equation. The RMS_{error} for these images was less than 0.83 pixel error (or approximately 24 meters). The images were georeferenced to the Universal Transverse Mercator (UTM) projection using the Clarke 1866 spheroid and the North American Datum 1927 (NAD27).

Adjustment of Radiometric Errors

A radiometric correction was performed on all TM bands to account for the systematic signal distortion of the sensor. One major source of distortion that occurs is the sensor offset. This is the residual noise that is recorded by the sensor when there is no input signal (Lillesand and Kiefer, 1987). The other major distortion is from the channel gain, which is the slope transfer relation between the signal received and the sensor's response. Differential offsets and gains between bands will cause problems when comparing their responses to a certain feature, so it is necessary to calibrate all the bands to each other. Gain and offset coefficients for each band are provided for by EOSAT for Landsat TM5. Correction for sensor deviation is given as:

$$L = (C*k)+L_{min} \qquad \textit{(Eq. 4)}$$

where L is the corrected response, C is the Digital Number (DN) value of the pixel, k is the gain, and L_{min} is the offset (Lillesand and Kiefer, 1987).

A sub-pixel analysis was run on the individual TM bands to detect inherent resampling errors such as Duplicate Line Artifacts (DLAs). These artifacts occur where a row or set of pixels of satellite imagery is duplicated during resampling to fill gaps in the data.

Field Survey Data and Image Analysis

The basis for the image classification is the field vegetation plot data. To ensure wide coverage over the entire Fort, an attempt was made to select beforehand in the GIS the approximate locations of field plots using a stratified random sampling procedure that incorporated general vegetation types, geomorphology, and soils within the boundaries of each 7.5' topographic quadrangle. Field crews implemented the design within the constraints of scheduling and the NMNHP sampling protocol calling for plots to be located within large stands of more or less uniform vegetation. A Global Positioning System (GPS) was used to record the highly accurate plot locations necessary for use in the image analysis. Most of the field data used in the image analysis was gathered during the 1995 and 1996 vegetation surveys, with additional data from prior NMNHP surveys conducted on the Fort (such data was used especially to fill in gaps in sampling within the Organ Mountains).

Landscape Unit Stratification

Landscape Units were created to aide spectral discriminations between different vegetation classes in production of the vegetation map. Different vegetation classes can have similar spectral signatures due to confounding effects of environmental features, a problem which increases with coverage of large, physiographically heterogenous sites. It has been shown that remotely sensed data alone has been an inadequate identifier of vegetation cover characteristics and this has led to many attempts to incorporate other ancillary data in the classification process (Niemann, 1993). To alleviate this problem, smaller subset areas (landscape units) were delineated within the larger Fort Bliss image on the basis of relatively homogeneous topography, elevation, slope, aspect, geology, surface substrate and known biotic distribution.

Image Classification

The image classification procedure synthesizes satellite image data with field plot data and ancillary data derived principally from Geographic Information System (GIS) coverages. The underlying concept of the mapping procedure is the digital integration of multiple, spatially related data sets. Initially, various digital data layers are created, followed by an interactive process of deriving statistical signatures from the image data, and finally an iterative process is used to create a preliminary vegetation classification.

Two principal data sets were used, the satellite image and the database information containing field plot data. These were converted into a spatially related data layer in the GIS along with DEMs, slopes, aspects, roads, hydrology, and elevation contours. All coverages were geographically referenced to the UTM coordinate system, using the NAD27 datum. These coverages were used interactively throughout the classification process, in order to verify field plot distributions, accuracy check, and ultimately to characterize mapping units.

A supervised classification strategy was adopted to create a preliminary vegetation map based on community types of the Fort Bliss vegetation community classification (Vol. 1). In contrast to an unsupervised classification which simply classifies an image into a predesignated number of mutually exclusive and more less arbitrary spectral classes, a supervised strategy develops spectral classes based on precise ground locations with known characteristics such as vegetation composition, rock type and landscape context.

The field data is applied to the TM image in the supervised classification through an interactive process called "seeding." In the seeding process, a pixel at the field plot location, was selected and its spectral characteristics were used to gather other similar contiguous pixels to create a statistical model or "seed" of the field plot. In an iterative process, the best seed models were constructed by adjusting the parameters of seed size (measured in hectares) and the within-seed spectral distance among pixels, and by comparing the resulting pixel distributions against the terrain models and the original imagery. Spectral distance is calculated as:

$$SD = \sqrt{\sum (\mu - X)^2} \qquad \textit{(Eq. 5)}$$

where SD is the spectral distance between pixels to the mean of the seed for all bands, μ is the mean of the seed for all bands, and X is the spectral value of pixel for all bands.

The size and spectral distance of the seeds were adjusted for each plot used in the classification. The plot occurrence size and shape were often determined by the estimated occurrences and site descriptions recorded on the plot sheets. Direct interpretation of the seed in the TM image on the screen also helped in determining the final size and shape of the seed. Slope and aspect models were used in conjunction with the field data and the TM image to verify seed shape and correct landscape position. Each seed is saved in a signature file with its field plot number, mean values for each image band, variance, number of pixels that were used to create the seed, and minimum and maximum value.

The supervised classification is performed using the statistics gathered in the seeding process. A supervised classification based on a maximum likelihood decision rule was used to perform the classification of the image data. This decision rule is considered the most accurate, because it not only uses a spectral distance such as the minimum distance decision rule, but it also takes into account the variance of each of the signatures. The variance is important when comparing a pixel to a signature representing, for example, a Chihuahuan scrub community which might be fairly heterogeneous, to a water class, which might be homogeneous. The maximum likelihood decision rule also contains a Bayesian classifier which uses probabilities to weight the classification towards particular classes. In this study the probabilities were unknown, so the maximum likelihood equation for each of the classes is given as:

$$D = -[0.5\ln(cov_c)]-[0.5(X-M_c)^T*(cov_c^{-1})*(X-M_c)] \qquad \textit{(Eq. 6)}$$

where D is the weighted distance, cov_c is the covariance matrix for a particular class, X is the measurement vector of the pixel, M_c is the mean vector of the class and ^{T} is the matrix transpose function (ERDAS, 1994). Each pixel is then assigned to the class with the lowest weighted distance. This technique assumes the statistical signatures have a normal distribution.

The classification was stratified by landscape unit and the results were analyzed and compared to proximal landscape units. Unfavorable outcomes based on informal accuracy checking with independent field data, air photos and other ancillary data, resulted in reclassification of the landscape unit by elimination and/or addition of particular seeded signatures that were problematic. All landscape units were then mosaicked together to create the preliminary vegetation map with as many map classes as seeds used in the classification.

Final Map Unit Development

Seed map classes were aggregated into a limited number of Mapping Units (MU's) for the final map based on floristic composition, landscape position, spatial contiguity, and spectral similarity, e.g. floristically similar seed classes which had similar landscape positions and were spatially near each other, were grouped into a mapping unit. This was an iterative process based once again on informal accuracy checking that was continued until all seed class as were grouped into the most consistent and accurate mapping units. Using an average linkage clustering method, Mapping Units were also checked for the degree of spectral homogeneity within a unit and to detect any outliers or potential groupings not previously recognized. The cluster analysis was performed on the spectral means of the individual classes from the preliminary vegetation map.

Final Vegetation Map

To create the final map, a filtering process was applied to create a minimum mapping unit size of 0.5 hectares. The procedure eliminates the "speckle" created by spatially solitary mapping units which have less than six contiguous pixels. The eliminated areas are then filled in by the majority of surrounding pixels using a 3 pixel x 3 pixel majority filter.

Roads, military cantonment and other highly disturbed areas were digitized and masked out (these areas were not sampled and therefore had no spectral class representing their distribution). Contiguous pixels are affected by the diffuse reflection (Lambertian reflection) from these areas, therefore, a buffer area was also assigned to compensate for these errors. However, some military disturbance sites and barren areas were sampled in the field and those were included in the classification process.

Spatial statistics about the mapping units were derived using the classified DEMs, aspect, and slope images. Although there are inherent problems in the original DEMs due to scan errors, we felt an overall summary of these units would be useful. Additionally, the size in hectares of the mapping units were calculated.

Map Validation

Accuracy testing of the map was performed using (1) field plots which were not used in the classification process and (2) randomly selected color frames extracted from airborne videography footage. There were 154 validation field plots and 680 videography validation points. Details of the of the validation process and results are provided in the Accuracy Assessment Supplement to this volume.

Software and Hardware Used

ERDAS Imagine, version 8.2 was the principal software used throughout the mapping process. All digital image and GIS coverages were either processed, manipulated, or used as overlays for analysis within the Imagine environment. The ERDAS Imagine software was loaded on a SUN workstation using a SUNOS Unix Operating System.

Arc/Info, version 7.03 was used to create, import, and manipulate vector coverages and Microsoft Access database ASCII files. This software package was loaded on a DEC Alpha Station. In addition, ArcView, version 3.0 was used to create maps and charts using both Arc/Info files and ASCII files from the Microsoft Access database. ArcView was loaded on a HP Pavilion Pentium, 133 Mhz. system.

PC based Microsoft Access database, version 2.0 was used to store and manipulate all field data as well as integrate ancillary data from other software sources such as EXCEL. This software was loaded on a 133 Mhz Micron Millennia

Trimble's Pfinder, version 2.0 PC software was used to differentially correct GPS data collected in the field to account for position errors due to Selective Ability (SA).

The Statistical Applications Software (SAS), Statgraphics and Systat for Windows statistical packages were used to manipulate image statistics and field data. The SAS program resides on the University of New Mexico network and Statgraphics and Systat were loaded in a PC network environment.

Results

Preliminary Analysis

Vegetation Indices

The Normalized Difference Vegetation Index (NDVI) out performed the Soil Adjusted Vegetation Index (SAVI) in the test areas. This was unexpected because SAVI was specifically designed to model green biomass in arid and semi-arid regions where much of the surface spectral response is dominated by soil. There were some areas on Otero Mesa which had burn scars registered anomalously high in the SAVI. These areas are near the escarpment, above large canyons and generally had shallow soils. This may indicate the SAVI was more influenced by soils than the NDVI. Due to this, the NDVI rather than SAVI was used in subsequent testing.

Stepwise Discriminant Analysis of TM Band Combinations

In decreasing order, TM bands 6, 1, 5, 7, NDVI, and 2 were significant in discriminating vegetation (Partial $R^2 = 0.7863$), but the stepwise discriminant analysis procedure consistently registered high overall error rates (> 0.401) using a variety of band combinations. Besides high overall error rates, other potential problems with this selection were also noted. The thermal band, TM6, consistently scored first on all stepwise analyses. This may be because the dynamic range in values for this band is smaller than for the reflective bands and the NDVI. Additionally, TM band 1 (blue) was also ranked high in most of the selection procedures. But TM1 is sensitive to atmospheric haze which causes a reduction in contrast. This can be overcome somewhat by substituting the highly correlated TM2 (green). The high correlation of these bands probably resulted in TM2 being relegated to the last selected position in the analysis, and hence TM1 and TM2 were be considered interchangeable in the selection order.

Evaluation of Different Image Processing Techniques

The image set containing TM1, TM2, TM5, TM7, and the NDVI was the most accurate at 76% correct at the Series level using the previously collected validation data set from Otero Mesa. The ratio image using band ratios (1) TM4/TM3; (2) TM4/TM5; (3) TM5/TM7 had a classification less accurate at 68%. The least accurate image at 60% was based on the first five components of a Principal Components Analysis (PCA) of all TM bands.

Discriminant Analysis Models of Vegetation Types

The image created using the discriminant function coefficients derived from the TM image significantly differentiated (p-value < 0.01) scrub and grassland communities. However, discrimination at the plant association level was less successful. This approach was also very time consuming requiring the duplication of the statistic gathering process.

Final Image Combination and Processing

Even the best accuracy (76%) indicated that problems of spectral overlap between classes still persisted. To help alleviate some these problems we decided to: (1) increase overall sampling density for field plots, (2) develop a sampling scheme to gather field plots of similar community types on diverse surface soil types and geomorphic position, and (3) obtain two satellite images representing two different seasonal conditions to enhance spectral differentiation.

Based on the results from the preliminary analysis a final geometric and radiometrically corrected 12-band image was compiled for subsequent image analysis and mapping. The new image included two NDVIs (rather than SAVI's) computed for both the winter and summer scenes and TM bands 2, 3, 4, 5, and 7 for each season. TM1 was rejected because of duplicate line artifacts (DLAs) detected with the sub-pixel analyzer. The DLAs were introduced into the images at EOSAT to account for drops in the data due to sensor malfunction. Our analysis uncovered an unacceptable amount of DLAs in both the summer and winter TM band 1 scenes. This band was replaced by the highly correlated TM2 (green). TM3 and TM4 were kept in the analysis even with NDVI's because the ratioing of these bands in the NDVI can mask the magnitude of their actual response, particularly TM4 (near infrared). Finally, TM7 was kept in the analysis because it is useful for detecting specific geologic substrates such as gypsum.

Landscape Unit Stratification

Twenty Landscape units were derived for the image classification stratification (Figure 3). These units effectively separated spectrally similar vegetation classes by limiting the distributions of the statistical signatures used to classify the image. For example, a highly vegetated spectral class dominated by Ponderosa Pine which has distribution at high elevations in the Organ Mountain Unit would be excluded with highly vegetated riparian areas of the

KEY

1	Sacramento Mountains	10	Hueco Mountains
2	Otero Mesa North	11	Hueco Mountains North
3	Otero Mesa South	12	Unnamed Hills
4	Sacramento Mountains Piedmont	13	McGregor Range
5	Otero Mesa Piedmont	14	Hueco Basin
6	Mack Tanks	15	Organ Mountains
7	Castner Draw	16	Organ Piedmont
8	Jarilla Piedmont	17	Organ Basin
9	Jarilla Basin	18	Central Basin
		19	Franklin Mountains
		20	Franklin Basin

Figure 3. Landscape units used to stratify of the Fort Bliss Vegetation Map image processing and map development. basin bottom. Each of the twenty landscape units is described in detail with respect to size and landscape structure in Appendix B.

Image Classification

The result of the image classification process was a preliminary vegetation map which spectrally and spatially represented the distribution of community types using the field vegetation plots. The preliminary map had over 1,000 seeded classes, representing the high spectral diversity of vegetation communities within the Fort as a function of the variety of plant communities, geological substrate, and topographic complexity. This map was used in its digital form only for development of the final map units.

Some difficulties did occur in the landscape stratification process. In some cases highly contrasting boundaries were created at the borders of the landscape units. Additionally, there was some uncertainty where units were under sampled for particular plant communities on specific geological substrates -- there can never be enough ground survey work to account for all contingencies. These problems were solved to some degree by including nearby seed spectral signatures from adjacent landscape units to account for the unit boundaries as well as areas where the geologic/soil substrate was continuous across the unit boundary, but sampled only on one side.

The issue of field undersampling was especially apparent in restricted areas of the Fort, such as the eastern side of the Organ Mountains and the impact areas south of Soledad Canyon which were either not sampled or undersampled. Where possible, previous field plots from earlier studies and aerial photo determined points were used to generate spectral statistics to enhance vegetation modelling for these areas, resulting in a better representation of this diverse landscape.

Map Unit Development and the Final Vegetation Map

Among the 1000 or more seed classes, floristically and physiographically similar classes were aggregated into 34 final Mapping Units used in the Final Vegetation Map (Table 3). Complete map unit descriptions can be found in Appendix C which describe the general vegetation composition and environmental characteristics of each unit and link each directly to the detailed community characterization abstracts of the vegetation classification presented in Volume I. Hence, one can get an overview of vegetation from the map unit descriptions and then can consult the community characterization abstracts for more specific information on species composition, environmental characteristics, ecological dynamics and management implications; the map and the vegetation classification are intended to be used together to create the most effective tool for resource planning.

To meet regional planning needs, a 1:120,000 scale map was produced which covers the entire Fort on one sheet and is located in the Back Pocket. This map has an hierarchical legend of the map units which groups them by major physiographic and vegetation characteristics. In addition we have produced 1:50,000 scale maps which correspond to the

Table 3. Fort Bliss Vegetation Map Units. Names are hierarchically structured with a more generalized physiographic name followed by a more precise name indicating the characteristics and usually dominant vegetation types within each mapping unit (MU).

MU	Physiographic Name	Map Unit Name	Ha.
1	Basin Desert Shrubland (Coppice Dunes)	Honey Mesquite/Sparse (Fourwing Saltbush)	131110
2	Plains/Coppice Dunes Sandscrub	Sand Sagebrush (Honey Mesquite)	15385
3	Plains Sandscrub	Sand Sagebrush/Mesa Dropseed	18734
4	Basin Desert Shrubland	Honey Mesquite/Alkali Sacaton	3042
5	Basin/Lowland Desert Shrubland	Tarbush with Tobosa, Sacaton and Burro Grasses	16384
6	Lower Piedmont Desert Shrubland	Creosotebush and Tarbush with Bush Muhly	36505
7	Lower Piedmont Desert Shrubland	Creosotebush with Honey Mesquite	2578
8	Upper Piedmont Desert Shrubland	Creosotebush/Bush Muhly (Mariola)	25965
9	Foothill Desert Shrubland	Viscid Acacia	17050
10	Foothill Desert Shrubland	Mimosa/Sideoats Grama	959
11	Foothill Desert Shrubland	Ocotillo-Mariola	4021
12	Foothill Desert Shrubland	Lechuguilla/Sideoats Grama	5591
13	Sandy Plains Desert Grassland	Mesa Dropseed/Soaptree Yucca	3225
14	Basin/Lowland Desert Grassland	Tobosagrass and Alkali Sacaton	15832
15	Basin/Lowland Desert Grassland	Burrograss	1284
16	Upper Piedmont Desert Grassland	Black Grama Grasslands	3040
17	Foothills/Piedmont Desert Grassland	Black Grama-Sideoats Grama (Creosotebush)	13204
18	Foothills Grassland	Sideoats Grama/Sacahuista	23288
19	Mesa Grassland	Blue Grama-Alkali Sacaton (Soaptree Yucca)	3025
20	Mesa Grassland	Black Grama-Blue Grama (Soaptree Yucca)	34397
21	Mesa Grassland	Black Grama-Blue Grama (Banana Yucca)	2312
22	Mesa/Foothills Grassland	New Mexico Needlegrass-Mixed Grama	7067
23	Foothills Grassland	Sideoats Grama, Curlyleaf Muhly and Mixed Shrubs	22247
24	Foothills Grassland	Sideoats Grama/Sotol and Hairy Grama/Sotol	2065
25	Montane Riparian	Boxelder, Velvet Ash, Willow and Apache plume	160
26	Montane Shrubland	Mountain Mahogany/Mixed Grass	9064
27	Montane Shrubland	Gambel's Oak-Whortleleaf Snowberry	290
28	Woodland	Oneseed Juniper/Mixed Grass	1168
29	Woodland	Pinyon Pine with Oak and Alligator Bark Juniper	2652
30	Forest	Ponderosa Pine and Douglas-Fir	150
31	Piedmont Grassland (Disturbed)	Arizona Cottontop, Three-awn and Grama Grasses	1509
32	Barren/Military	Rock, Barren Soil, Military Cantonment and Impact Areas	1462
33	Military Facilities	Military Facilities	7619
34	Roads	Roads	18209

15 minute topographic maps typically used by the Fort for more specific site planning. An example of one of these sheets is also provided in the Back Pocket with a legend ordered by map unit number which correspond to the map unit numbers of Table 3 and the numbers in the descriptions. For all maps, the minimum map unit polygon size is 0.5 ha.

In general, spatial statistics derived from the mapping units using the digital terrain, show most of the map units have distinct distributions defined by elevation, slope, and aspect (Table 4, 5 & 6). The Basin Desert Shrublands and Lowland Desert communities are mostly limited to the lower elevations, the majority falling below 4500 feet. Gambel's Oak and Pinyon Pine with Oak (MUs 27 & 30) are found on steep slopes, greater than 41% in the Organ and Sacramento Mountains. Gambel's Oak (MU 27) has an affinity to northerly aspects whereas mimosa/sideoats grama, sideoats grama/sacahuista, and sideoats grama/sotol (MUs 10, 18 & 24) show more southerly aspects. Mesa grasslands tend to occur on mildly undulating reliefs and therefore have no significant aspect or slope correlations; however, Black Grama-Blue Grama with Banana Yucca (MU 21) is largely distributed at higher elevations similar to the New Mexico Needlegrass-Mixed Grama grasses (MU 22). We were also able to spectrally distinguish based on cluster analysis between some black grama and blue grama grasslands on Otero Mesa, including the sub-mesa areas, as well as sotol grasslands within the Organ piedmont. An example of the cluster analysis is given in Appendix D.

However, some map units had bi-modal distributions; Tarbush dominated units can extend to higher elevations, usually following drainages (MU 5), and MUs 14 & 15 which are dominated by tarbush, tobosagrass, alkali sacaton, and burrograss commonly occur in the basin bottom but have substantial occurrences on northern Otero Mesa as well.

Discussion

The hard copy maps were produced here at scales which we think are most effective for current planning practices, but they exist in digital form and can be reproduced at much finer or coarser scales. We recommend that the maps be used at scales of 1:50,000 or coarser. This is in part because there are inherent limits to resolution of meaningful vegetation pattern as function of TM imagery and available ancillary data, and because these maps have been filtered to produce the minimum map unit size of 0.5 hectares. Operationally, polygon sizes of one hectare or less need to be used with caution. But maps at the recommended scales can be very useful in identifying areas where future, more detailed map work might be needed for project level, highly site specific planning.

The maps in digital form can be readily integrated into a GIS and used with software such as ARCVIEW to produce desktop applications to be directly and effectively used in a flexible planning process. Furthermore, the maps themselves can be readily updated and upgraded. These maps were essentially built on the basis of only one year's worth of data gathering, and many areas of the Fort remain to be visited and described. Hence, these maps should not be considered static, unchanging views of vegetation on Fort Bliss, but rather as changeable maps that can be enhanced as new information becomes available.

Table 4. Distribution of elevations within map units by elevation classes in feet.

Map Unit	<4000	4001-4500	4501-5000	5001-5500	5501-6000	6001-6500	6501-7000	7001-7500	7501-8000	8001-8500	8501-9000
1	15.55	84.23	.21								
2	16.39	83.12	.48								
3	0.45	96.22	2.32	0.76	.21	.01	.03				
4	4.12	95.66	.15	.07							
5	2.79	44.63	32.28	19.05	0.86	0.37	0.02				
6	0.78	84.86	12.85	1.44	.06	.01					
7	9.63	85.49	4.88								
8	0.32	74.40	19.16	4.65	.99	.39	.08				
9		30.39	53.76	9.87	4.0	1.89	.08	.01			
10		2.01	15.93	20.99	24.86	19.61	9.43	5.19	1.64	.34	
11		55.5	32.17	7.34	3.04	1.27	.39	.11	.14	.04	
12		6.59	33.81	47.81	11.75	.05					
13	31.36	68.64									
14	5.34	22.04	53.91	17.36	.81	.49	.05	.01			
15	2.32	70.12	26.72	.81	.02						
16	30.21	53.93	11.70	3.60	.32	.12	.12				
17	.05	20.73	49.89	21.91	4.75	1.50	0.97	0.12	0.05	0.03	
18		3.52	22.36	52.21	14.91	6.64	.35	.01			
19			39.43	60.15	.33	.06	.02				
20		1.75	51.41	46.09	.66	.07	.02				
21	.01	2.44	12.81	82.13	.94	.83	.84				
22			7.74	91.81	0.43	0.03					
23		7.06	22.34	23.27	23.35	18.65	4.04	.92	.31	.07	
24		11.82	25.42	17.94	20.36	14.45	6.55	2.28	.85	.32	.02
25			0.14	18.95	45.23	20.71	6.79	4.51	2.76	.9	
26		.12	1.09	4.31	22.07	47.16	18.44	4.23	1.76	.79	.05
27			.03	.25	.34	1.23	5.54	21.01	38.43	30.15	3.02
28		.01	.37	2.93	24.36	59.84	10.61	1.27	0.45	0.15	
29			.18	1.49	5.97	15.02	43.08	22.53	9.86	1.80	0.07
30				0.05	0.05	1.14	7.9	26.35	40.96	22.08	1.46
31	0.01	54.09	39.18	4.97	0.71	0.39	0.64				

Table 5. Percent slope distribution within map units by percent slope classes.

Map Unit	0-3%	4-8%	9-15%	16-30%	41-35%	46+%
1	99.47	0.49	0.03	0.01	0.00	0.00
2	98.05	1.63	0.24	0.07	0.00	0.00
3	95.25	3.35	1.0	0.33	0.06	0.01
4	98.18	1.21	0.43	0.18	0.0	0.0
5	84.51	12.30	2.34	0.70	0.12	0.03
6	89.16	8.91	1.48	0.38	0.06	0.02
7	73.40	23.81	2.65	0.13	0.0	0.0
8	68.67	20.08	5.44	3.19	1.59	1.04
9	22.56	37.77	21.40	12.48	4.23	1.56
10	1.28	3.45	12.96	24.10	17.68	40.52
11	21.38	30.34	18.11	11.99	7.47	10.72
12	3.21	11.11	18.73	38.12	20.76	8.07
13	99.01	0.88	0.08	0.01	0.01	0.00
14	87.53	9.43	1.82	0.78	0.30	0.13
15	99.34	0.56	0.06	0.02	0.01	0.00
16	70.52	19.40	7.22	1.83	0.53	0.50
17	41.35	23.60	12.43	12.28	5.99	4.35
18	22.23	30.41	19.65	19.05	6.70	1.96
19	84.47	14.34	1.07	0.11	0.00	0.00
20	78.59	17.58	2.45	0.95	0.27	0.16
21	77.15	18.09	1.27	0.94	0.90	1.65
22	55.51	40.46	3.18	0.72	0.11	0.02
23	7.87	14.30	16.56	28.88	17.83	14.56
24	4.50	13.49	24.84	25.13	13.80	18.24
25	0.33	5.61	15.11	41.38	17.53	20.05
26	1.46	6.83	17.73	36.76	19.87	17.35
27	0.00	0.17	0.67	5.65	14.55	78.97
28	2.41	13.16	29.06	33.12	11.41	10.83
29	0.75	5.05	13.83	23.37	14.24	42.76
30	0.0	0.11	0.49	5.25	17.69	76.46
31	46.18	33.57	11.97	5.66	1.45	1.17

Table 6. Aspect distribution within map units by aspect class. Aspect class ranges in degrees azimuth are: NE >=30 and <60, NNW >0 and <30 and >=300, E/W >=60 and <120 or >=240 and <300, SSE >=120 and <210, SW >=210 and <240.

MU	NE	NNW	E/W	SSE	SW	NONE
1	0.0	0.01	0.01	0.02	0.0	99.95
2	0.02	0.05	0.11	0.11	0.03	99.67
3	0.08	0.33	0.35	0.44	0.20	98.59
4	0.03	0.09	0.15	0.29	0.06	99.37
5	0.39	0.75	1.16	0.59	0.24	96.85
6	0.22	0.29	0.64	0.59	0.15	98.09
7	0.29	0.45	0.93	0.64	0.47	97.22
8	0.77	2.40	3.80	3.04	1.09	88.84
9	2.13	7.21	12.39	12.40	5.34	60.34
10	9.41	2.87	34.31	41.85	6.82	4.73
11	3.18	4.51	18.54	17.43	4.53	51.72
12	7.62	25.40	32.01	14.01	6.12	14.32
13	0.01	0.01	0.04	0.06	0.01	99.88
14	0.19	0.42	0.85	1.34	0.22	96.97
15	0.01	0.07	0.07	0.02	0.01	99.82
16	1.74	1.54	3.61	1.50	1.64	89.92
17	3.04	9.35	13.43	6.16	2.86	64.95
18	3.07	8.17	14.47	14.74	6.71	52.66
19	0.13	0.28	0.39	0.36	0.06	98.77
20	0.34	0.90	1.26	0.85	0.41	96.22
21	0.17	0.32	1.49	2.31	0.45	95.23
22	0.34	1.53	1.04	0.55	0.51	95.97
23	3.55	18.20	25.82	22.02	7.93	22.20
24	8.51	2.13	34.14	29.19	8.01	18.00
25	12.68	30.88	20.86	18.10	10.83	5.94
26	6.11	25.93	32.97	16.64	9.58	8.30
27	22.41	43.38	21.28	9.15	2.57	0.17
28	13.15	14.59	26.13	20.17	10.06	15.57
29	9.27	25.19	35.67	14.95	8.73	5.8
30	8.39	44.75	27.71	14.39	3.57	0.11
31	1.59	0.67	9.58	7.57	0.83	79.75

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APPENDIX A

Imagery and GIS Coverage MetaData

The following is a list of the principal digital files used in the mapping process. Those listed in **bold** are the deliverable digital files. File formats and pertinent information about the files are listed below.

Data sets :

A. Raster Images

1. TM Scenes
ERDAS Imagine (**.img** format)

Summer Full Scene - Landsat 5 TM
Acquired 9/19/93
Path 33 / Row 37 (50% scene shift)
Rows 5965 Columns 6967
Sun Elevation 48°
Sun Azimuth 132°

Summer Sub-scene - Landsat 5 TM
Acquired 8/8/92
Path 32 / Row 38
Sun Elevation 56°
Sun Azimuth 111°

Winter Full Scene - Landsat 5 TM
Acquired 2/10/94
Path 33 / Row 37 (50% scene shift)
Rows 5965 Columns 6967
Sun Elevation 33°
Sun Azimuth 139°

Winter Sub-scene - Landsat 5 TM
Acquired 1/25/94
Path 33 / Row 37 (50% scene shift)
Rows 3510 Columns 3510
Sun Elevation 29°
Sun Azimuth 142°

2. Combined Summer and Winter Scenes (**blisstm.img**)
Landsat TM bands (parenthesis is band order):

(1) Summer TM2
(2) Summer TM3
(3) Summer TM4
(4) Summer TM5
(5) Summer TM7
(6) Winter TM2
(7) Winter TM3
(8) Winter TM4
(9) Winter TM5
(10) Winter TM7
(11) Summer NDVI
(12) Winter NDVI

3. USGS DEMs 1:24,000

Elevation - raw data merged (**blissdem.img**)
Elevation - classified (**nmnhpdem_rec.img**)
(Parenthesis is class order)
(1) < 4000'
(2) 4001' - 4500'
(3) 5001' - 5500'
(4) 5501' - 6000'
(5) 6001' - 6500'
(7) 6501' - 7000'
(8) 7001' - 7500'
(9) 7501' - 8000'
(10) 8001' - 8500'
(11) 8501' - 9000'
(12) 9001 - 9500'

Slope - classified (**nmnhpslope_rec.img**)
(Parenthesis is class order)
(1) 0 - 3%
(2) 4 - 8%
(3) 9 - 15%
(4) 16 - 30%
(5) 31 - 45%
(6) 46% +

Aspect - classified **(nmnhpasp_rec.img)**
(Parenthesis is class order)
(1) NE
(2) NNW
(3) E-W
(4) SSE
(5) SW
(6) None

4. Vegetation Map **(nmnhp_veg.img)**
Developed 1996
Classified Image
34 Mapping Units

B. Vector Coverages - ArcInfo (**.e00** compressed format)

1. Line Coverages **(nmnhp_cont.e00)**

USGS DLGs - hydrology and roads

USGS DEMs 1:24,000 - contours/ 80' intervals

2. Point Coverages **(nmnhp_gis.e00)**

NMNHP GIS - field plots attributed

3. Polygon Coverages **(nmnhp_bio.e00)**

Fort Bliss GIS- soils/small scale
soils/large scale
boundary

NMNHP GIS -landscape units

Appendix B

Landscape Unit Descriptions

For easy reference, landscape units, including basin and piedmont units, are grouped and described by the mountain range to which they are closest. There are five mountain range groupings: I. Sacramento Mountains; II. Jarilla Mountains; III. Hueco Mountains; IV. Organ Mountains, and V. Franklin Mountains. This grouping does not necessarily reflect actual geomorphic processes on the ground: some units are influenced by more than one mountain range or by other processes not related to the mountains. Refer to Figure XX for a map of the landscape unit boundaries, numbers in front of the landscape units correspond to the numbers on the map.

I. SACRAMENTO MOUNTAINS

(1) Sacramento Mountains (Area: 33,750 Ha)

This large unit comprises the southern end of the Sacramento Mountains which are at the northeastern border of Fort Bliss. The elevational range is 4450 to 7700 feet. Overall, as a range, the Sacramento Mountains dip to the east, but this area is made up of a complex of limestone foothills of diverse aspects alternating with steep-sided canyons and narrow to moderately wide valleys. Shallow limestone colluvium is the primary parent material on the slopes, but isolated sand sheets cover some slopes near the western edge of the site. In addition, gravelly and silty alluvium is found near the southern boundary of the site, where the mountain streams drain onto Otero Mesa. Vegetation is predominantly conifer woodland and Rocky Mountain deciduous scrub in the upper elevations, sand-scrub on the sandsheet and Chihuahuan desert scrub at lower elevations.

(2) Otero Mesa North (Area: 37,350 Ha)

The Otero Mesa North unit is on Otero Mesa between the Sacramentos to the north and the mid-mesa uplift to the south. Elevation is between 4700 and 5600 feet. This area is a tableland with a broad drainage system that originates in the Sacramento Mountains to the north and in the higher area near the escarpment to the west. Most of the site consists of gently rolling hills with deep, medium to fine textured soils. Piedmont is a minor landform limited to the northern boundary of the site near the Sacramento Mountains. Vegetation is predominantly black and blue grama that occurs in a transitional zone between Chihuahuan desert and Plains-Basin grasslands. Swale grasslands with tobosagrass and burrograss occur in depressions and broad drainage systems -- near the piedmont, these often have a tarbush component.

(3) Otero Mesa South (Area: 28,000 Ha)

The Otero Mesa South unit is on Otero Mesa and extends from the mid-mesa uplift in the north to the southern tip of the Mesa. Elevation is between 4550 and 5950 feet. The area is a tableland with drainages that originate from the Sacramento Mountains to the east and north. This unit consists of rocky, rolling limestone hills with shallow soils and shallow upland valleys. Small colluvial slopes are associated with the mid-mesa rise, drainageway borders, and the mouth of canyons near the escarpment. Vegetation is similar to that of Otero Mesa North with much of the area covered by grassland that is transitional between the Chihuahuan desert and the Plains-Basin biomes with inclusions of tobosagrass, burrograss and tarbush in the silty depressions. The shallower soils, however, favor a slightly different mix of species. More pure stands of black grama are found here. In addition, New Mexico needlegrass frequently occurs on rocky slope ridges, and blue grama is often restricted to mesic areas in depressions with tobosagrass.

(4) Sacramento Mountains Piedmont (Area: 17,200 Ha)

This unit is in northern McGregor Range, west of the Sacramento Mountains and east of the Tularosa Basin bottom. Elevation ranges from 4100 and 5100 feet. The site is predominantly Sacramento Mountain and Otero Mesa piedmont with active and remnant alluvial surfaces dissected by drainages that originate from the west and northeast on the Sacramento Mountains and from the southeast on Otero Mesa. The northernmost section of Otero Mesa escarpment is at the southeast corner of the unit and some small, separate colluvial hills are scattered between the upper piedmont. The piedmont grades into sandy basin bottom on the extreme western edge of the unit. With the exception of the sand on the basin floor, all soils are derived from limestone parent material. Soils are shallow and rocky on the steep slopes of the Mesa escarpment, where vegetation is a mix of desert scrub and grassland (mostly sideoats and curlyleaf muhly). On lower piedmont flats the vegetation is primarily shrubland. Shallow, but well-developed, clayey soils on the colluvial hills and remnant alluvial surfaces support viscid acacia. Shrubby creosote and mariola communities are on the coarse, rocky soils of the upper piedmont, and grade into pure stands of creosote further down on the more gravelly piedmont. Tarbush stands occur at still lower elevations, on flatter areas with silty soils. Mesquite stands are on the sandy soils at the base of the piedmont.

(5) Otero Mesa Piedmont (Area: 24,000 Ha)

Including Rough Canyon, this unit is in the north-central portion of McGregor Range, west of central Otero Mesa and east of the Jarilla Mountains. Elevation is between 4100 and 5950 feet. The site is predominantly Otero Mesa piedmont with active and remnant alluvial surfaces dissected by drainages originating to the east on Otero Mesa. A section of Otero Mesa escarpment and small, separate colluvial hills at the base of Otero Mesa are included within the eastern edge of the unit. The piedmont grades into sandy basin bottom on the western edge of the unit. With the exception of the sand on the basin floor, all soils are derived from limestone parent material. Soils are shallow and rocky on the steep slopes of the escarpment, where vegetation is a mix of desert scrub and grassland (mostly sideoats and curlyleaf muhly). Soils on the colluvial hills and remnant alluvial surfaces are also shallow, but well-developed and often clayey; these moderately graded slopes support stands of viscid acacia. Black grama grasslands are often in a band between the upper piedmont and the escarpment bottom on gravelly, loamy soils. Creosotebush communities dominate most of the site. They occur on the gentle slopes of the gravelly, loamy piedmont, while tarbush stands and lowland desert grasslands are on the siltier soils associated with drainages near the lowest part of the piedmont. Mesquite and sandsage occur on the small inclusions of sandy basin floor at the base of the piedmont.

(6) Mack Tanks (Area: 10,800 Ha)

The Mack Tank unit is in the east-central portion of Fort Bliss, lying west of central Otero Mesa, southeast of the Jarilla piedmont, and north of the Hueco Mountains. Elevation is between 4100 and 4900 feet. The site is a broad, gently sloping, shallow depression composed of limestone alluvium originating from the Hueco Mountains and Otero Mesa. Soils are coarse and silty loams. Vegetation is desert scrub dominated by creosotebush on the coarser soils and by tarbush on the siltier soils. Mesquite and sandsage occur on patchy sandy pockets and viscid acacia is found on the rarely occurring shallow colluvial soils.

(7) Castner Draw (Area: 19,200 Ha)

This unit is immediately below the southern Otero Mesa rim and is bordered by the Mesa escarpment to the east and the Hueco Mountains to the west. Elevation is between 4550 and 5500 feet. Major landforms are the Mesa escarpment, Mesa alluvial piedmont (active and remnant) and low colluvial hills and tablelands created by separate, later, uplift events. Slopes are correlated with the landform: steep slopes on the scarp faces, moderate slopes on the hills and gentle to flat slopes on the tablelands and lower piedmont. Soils are shallow and rocky on the Mesa escarpment, and shallow but well-developed on the colluvial slopes and remnant alluvial surfaces. In the alluvial piedmont that surrounds and fills the lower areas between the hills, soils grade from gravelly loam to silt as the piedmont surface slope down towards the basin to the west. Vegetation of the low tablelands is very similar to that of Otero Mesa, being predominantly black and blue grama grasslands that are transitional between Chihuahuan Desert and Plains-Mesa Grassland with inclusions of New Mexico needlegrass on the rocky ridges. A mix of desert scrub and grassland predominates on the escarpment slopes with viscid acacia on remnant alluvial surfaces and colluvial slopes. Creosotebush is on the gravelly piedmont and tarbush communities occur below on the siltier soils.

II. JARILLA MOUNTAINS

(8) Jarilla Piedmont (Area: 3,400 Ha)

This small unit near Orogrande close to the central-northern boundary of the Fort is broken up by Fort boundaries into two sections. Elevation ranges from 4000 to 5000 feet. One section is a long narrow strip along the eastern Jarilla Mountain front stretching in a narrow northeast-southwest strip east of US Highway 54 and the Jarilla Mountains. It is comprised of the lower piedmont of the Jarilla Mountains grading to basin bottom. The alluvium are igneous, sedimentary, and metamorphic units of the Jarillas which extend gradually to meet the Holocene deposits of the basin floor. Portions of the distal footslopes underlie recent eolian deposits. The other section is a small unit south of Orogrande Base Camp comprising two small granitic hills with associated piedmont and, near the area of the surrounding basin, sandsheet. Vegetation is predominantly creosotebush and mixed desert grassland. It occurs on shallow soils of the moderately steep hillslopes and also on the gravelly loamy soils of the gentle slopes near the mountain front. Sandscrub occurs on the shifting sands near the piedmont-basin transition. The shifting sands grade into, but do not include, the mesquite coppice dunes of the basin floor.

(9) Jarilla Basin (Area: 26,400 Ha)

This unit is a narrow site that runs north-south at the northwestern edge of McGregor Range east and northeast of the Jarilla Mountains and west of the Sacramento Mountains and Otero Mesa. Elevation is between 4100 and 4700 feet. It is sand-covered basin bottom grading to lower piedmont on its eastern edge. Shifting sands are the predominant landform, but there are also coppice dunes and small playas. Vegetation is mostly sandsage with smaller amounts of mesquite and mesa dropseed. Tarbush increases towards the piedmont.

III. HEUCO MOUNTAINS

(10) Hueco Mountains (Area: 15,500 Ha)

The medium-sized Hueco Mountains unit is at the southeastern-most border of the Fort. It is exclusive to the lower, northern foothills of the Huecos (Hueco Mountains North Unit). Elevation is from 4500 to 6000 feet. Steep, limestone mountain and hill slopes with shallow soils alternate with narrow to broad mountain valleys which drain northwest through alluvial piedmont to the Heuco Bolson floor. Lechugilla, creosotebush and mariola dominate the shallow soils on the steep, rocky limestone slopes while sideoats and occasional black grama desert grasslands occupy gentler slopes as well as gravelly, somewhat deeper soils on the footslopes and upper piedmont. The lower piedmont supports creosotebush communities.

(11) Hueco Mountains North (Area: 10,250)

This unit is located in the east-central portion of Fort Bliss, north of the Hueco Mountains. Elevation ranges from 4100 to 5100 feet, averaging 800 feet lower than that of the Hueco Mountain site to the south. It is an irregularly shaped area comprised of the northernmost foothills of the Hueco Mountains and smaller, disjunct hills created by separate uplift events that are northwest and southeast from the Huecos. The Hueco mountain slopes are steep limestone dipping to the northeast with narrow to broad upland valleys draining northwest and southwest through piedmont to the Hueco Bolson floor. The rocky, shallow soils and rock outcrops of these slopes support diverse stands of desert scrub. The hills are moderate to gentle graded slopes composed of limestone colluvium and are separated from the mountain mass and each other by lower extensions of the Otero Mesa piedmont. Extensive stands of viscid acacia are on the colluvial hills which have shallow, but well-developed clayey soils. Desert grassland and creosotebush communities are on the gravelly loams of both the Heuco and Otero Mesa piedmont. Tarbush communities and lowland desert grassland vegetation predominate in the silty soils of the lower piedmont near the basin.

(12) Unnamed Hills (Area: 2100 Ha)

The Unnamed Hills is a small unit at the lower southeast corner of Fort Bliss, southwest of the Hueco Mountains. Elevation ranges from 4200 to 5100 feet. The hills are a group of small limestone uplifts, with high relief slopes, narrow canyons and associated piedmont. Lechugilla and creosotebush scrub predominate on the slopes which are mostly rocky, shallow, limstone soils. Alluvial deposits on upper piedmont surfaces support sideoats and black grama grasslands, with creosote below on the gravelly, silty soils of the lower piedmont.

(13) McGregor Range (Area: 24,000 Ha)

This fairly large unit is a north-south band which extends from the central to the southeast portion of McGregor Range and is broken into two sections by Fort Bliss Boundaries. It is comprised of the western front of the Hueco Mountains and the Unnamed Hills. Elevation is from 4100 to 5200 feet. Major landforms are alluvial fans with broad interfan and intermountain depressions which drain northwest into the basin bottom. There are three small, colluvial limestone hills within the site. Desert scrub (mostly creosotebush and lechugilla) with scattered inclusions of desert grassland occur on the shallow rocky soils of the moderately steep hillslopes and on the gentler graded gravelly piedmont. Tarbush predominates on the lower, gently grading to flat bottom areas with siltier soils. Sandy soils on the piedmont to basin bottom transition support sandscrub, mesquite, and a mix of mesa dropseed and creosotebush.

(14) Hueco Basin (Area: 32,100 Ha)

This unit is in the central southern portion of McGregor Range. It is west of the Hueco Mountains and McGregor Range Camp and northwest of the Unnamed Hills unit. Elevation is between 4000 and 4200 feet. Generally, sandsheets occupy the northern half of this unit, while coppice dunes occupy the south. Vegetation on the sandsheets is sandsage, with mesa dropseed occurring in lower areas. Mesquite dominates the coppice dunes in the south.

IV. ORGAN MOUNTAINS

(15) Organ Mountains (Area: 10,250 Ha)

This unit encompasses the slopes of the Organ Mountains which are at the northwest border of Fort Bliss. Elevation ranges from 4500 to 9000 feet. Topographic relief is very high with steep, precipitous slopes alternating with deep canyons. The central portion of the range and the eastern slopes are predominantly of plutonic stock with some large exposed units of granites along the central eastern slopes of the range and Rattlesnake Ridge. Rhyolites cover much of the western and southwestern portions of the range. Sedimentary units lie on the crest and western slopes of Rattlesnake Ridge. Steep elevation gradients combine with diverse geologic substrates to support the highest vegetation diversity of any landscape unit on Fort Bliss. The mountains support Rocky Mountain coniferous forest and woodlands, montane scrub and meadows. Canyons support diverse Madrean woodland and grassland riparian communities while Chihuahuan desert grassland and scrub are at lower elevations.

(16) Organ Piedmont (Area: 21,000 Ha)

This unit is near the western boundary of Fort Bliss east and south of the Organ Mountains and north of the Franklin Mountains. Elevation is between 4000 and 5500 feet. The site is comprised of the gently sloping Organ and Franklin Mountains piedmont, dissected by drainages originating from the west in the Organs and from the southwest in the Franklins. There is one isolated basaltic hill near the mountain front. The eastern edge of the unit grades into basin bottom. Soils on the piedmont are derived from granitic, rhyolitic, limestone and sandstone alluvium which support a mix of desert scrub (mostly creosotebush and mimosa) and grassland. Sandier soils near the basin bottom support increasing numbers of mesquite in transitional communities mixed with creosotebush and black grama.

(17) Organ Basin (Area: 28,650 Ha)

This unit is near the western edge of Fort Bliss, below and east of the Organ Mountains. Elevation is between 3900 and 4400 feet. The site lies at the western edge of the large coppice dune field of the Central Basin. Coppice dunes dominate the eastern half of the unit but fade towards the center to the sandy flats at the base of the Organ Mountain piedmont (the western edge of the unit). Vegetation is mesquite on the coppice dunes, with increasing four-wing saltbush towards the southwest. Sparse desert grasslands occupy the sandy flats, and creosotebush is found as the flats grade upward onto piedmont.

(18) Central Basin (Area: 75,850 Ha)

This large unit is in the center of Fort Bliss, east of the Organ Mountains, southwest of the Jarilla Mountains, west of the Sacramentos and northwest of the Huecos. Elevation is between 4000 and 4300 feet. The unit is basically a large coppice dunefield, but shifting sands increase towards the eastern and northern edges of the unit which abuts piedmont. Small depressions are scattered, but infrequent. The area is flat to gently sloping overall. Mesquite is the dominant vegetation in the dune field, with four-wing saltbush, sandsage and mesa dropseed increasing as the shifting sands increase near the piedmont. There is a rare occurrence of desert grassland in the center of the unit.

V. FRANKLIN MOUNTAINS

(19) Franklin Mountains (Area: 850 Ha)

This small unit is comprised of two, narrow, disjunct areas of the northern end of Franklin Mountains near the western boundary of the Fort. Elevation ranges from 4300 to 5500 feet. The southernmost part of this unit is a hogback with exposed limestone outcrops alternating with very coarse, sandstone and siltstone colluvium. The northern part of this unit is made up of two small hills separated by a saddle. Vegetation is a mix of desert scrub. Creosotebush communities are on the immediately surrounding piedmont.

(20) Franklin Basin (Area: 28,300 Ha)

This large unit is at the southernmost part of McGregor Range, and is part of the larger Hueco Bolson to the north and east. It is northeast of El Paso and east of the Franklin Mountains. Elevation is between 3950 and 4300 feet. The site is comprised predominantly of coppice dunes, but shifting sands increase towards the south as do minor inclusions of small playas. The area is flat to gently sloping. Mesquite dominates the entire area, but other species (mesa dropseed and four-wing saltbush) increase in the shifting sands to the south. This is the closest site to El Paso, and, as such, there are extensive roads throughout.

Appendix C

Map Unit Descriptions

This appendix contains descriptions for the 34 map units (MU) listed below used in the Fort Bliss Vegetation Map. Each description details the major vegetation community types and major inclusions that can occur (inclusions occupy less than 10% of the distribution of the map unit). A short narrative describing overall character of the map unit and the distribution of the major community types is provided. Detailed descriptions of each community type can be found in Volume I, the Vegetation Classification for Fort Bliss, Texas and New Mexico.

MU	Physiographic Name	Map Unit Name	Ha.
1	Basin Desert Shrubland (Coppice Dunes)	Honey Mesquite/Sparse (Fourwing Saltbush)	131110
2	Plains/Coppice Dunes Sandscrub	Sand Sagebrush (Honey Mesquite)	15385
3	Plains Sandscrub	Sand Sagebrush/Mesa Dropseed	18734
4	Basin Desert Shrubland	Honey Mesquite/Alkali Sacaton	3042
5	Basin/Lowland Desert Shrubland	Tarbush with Tobosa, Sacaton and Burro Grasses	16384
6	Lower Piedmont Desert Shrubland	Creosotebush and Tarbush with Bush Muhly	36505
7	Lower Piedmont Desert Shrubland	Creosotebush with Honey Mesquite	2578
8	Upper Piedmont Desert Shrubland	Creosotebush/Bush Muhly (Mariola)	25965
9	Foothill Desert Shrubland	Viscid Acacia	17050
10	Foothill Desert Shrubland	Mimosa/Sideoats Grama	959
11	Foothill Desert Shrubland	Ocotillo-Mariola	4021
12	Foothill Desert Shrubland	Lechuguilla/Sideoats Grama	5591
13	Sandy Plains Desert Grassland	Mesa Dropseed/Soaptree Yucca	3225
14	Basin/Lowland Desert Grassland	Tobosagrass and Alkali Sacaton	15832
15	Basin/Lowland Desert Grassland	Burrograss	1284
16	Upper Piedmont Desert Grassland	Black Grama Grasslands	3040
17	Foothills/Piedmont Desert Grassland	Black Grama-Sideoats Grama (Creosotebush)	13204
18	Foothills Grassland	Sideoats Grama/Sacahuista	23288
19	Mesa Grassland	Blue Grama-Alkali Sacaton (Soaptree Yucca)	3025
20	Mesa Grassland	Black Grama-Blue Grama (Soaptree Yucca)	34397
21	Mesa Grassland	Black Grama-Blue Grama (Banana Yucca)	2312
22	Mesa/Foothills Grassland	New Mexico Needlegrass-Mixed Grama	7067
23	Foothills Grassland	Sideoats Grama, Curlyleaf Muhly and Mixed Shrubs	22247
24	Foothills Grassland	Sideoats Grama/Sotol and Hairy Grama/Sotol	2065
25	Montane Riparian	Boxelder, Velvet Ash, Willow and Apache plume	160
26	Montane Shrubland	Mountain Mahogany/Mixed Grass	9064
27	Montane Shrubland	Gambel's Oak-Whortleleaf Snowberry	290
28	Woodland	Oneseed Juniper/Mixed Grass	1168
29	Woodland	Pinyon Pine with Oak and Alligator Bark Juniper	2652
30	Forest	Ponderosa Pine and Douglas-Fir	150
31	Piedmont Grassland (Disturbed)	Arizona Cottontop, Three-awn and Grama Grasses	1509
32	Barren/Military	Rock, Barren Soil, Military Cantonment and Impact Areas	1462
33	Military Facilities	Military Facilities	7619
34	Roads	Roads	18209

Fort Bliss Vegetation Map Unit Description — No.: 1

Basin Desert Shrubland (Coppice Dunes)
Honey Mesquite/Sparse (Fourwing Saltbush)

Major Community Types

CT 1: honey mesquite/sparse undergrowth	***Prosopis glandulosa/Sparse***
CT 2: honey mesquite-fourwing saltbush	***Prosopis glandulosa-Atriplex canescens***
CT 3: honey mesquite/mesa dropseed	***Prosopis glandulosa/Sporobolus flexuosus***

Inclusions

Incl 1: honey mesquite/sparse undergrowth, tarbush	***Prosopis glandulosa/Sparse, Flourensia cernua phase***
Incl 2: purple threeawn/sparse undergrowth	***Aristida purpurea/Sparse***
Incl 3:	

Description

This Desert Shrubland is comprised of the large coppice dunefield on the Tularosa Basin. Honey Mesquite/Sparse is the dominant community, occupying the central portion of the basin and making up 77% of the map unit. The Honey Mesquite/Fourwing Saltbush type is 15% of the map unit and located near the north edge of the dunefield. Honey Mesquite/Mesa Dropseed communities are near the southern and eastern edge of the dune field and is 6% of the map unit. Three-awn grasslands are scattered to the west and east on the basin-piedmont transition.

Fort Bliss Vegetation Map Unit Description   No.: 2

Plains/Coppice Dunes Sandscrub
Sand Sagebrush

Major Community Types

CT 1: sand sagebrush/sparse undergrowth *Artemisia filifolia/Sparse*
CT 2: sand sagebrush/mesa dropseed *Artemisia filifolia/Sporobolus flexuosus*
CT 3:

Inclusions

Incl 1:

Incl 2:

Incl 3:

Description

The Sand Sagebrush/Sparse with a Honey Mesquite phase is the dominant community type, making up 83% of this Sandscrub community. Sand Sagebrush/Mesa Dropseed comprises the remaining 17%. These are transitional shrublands between the sand sheet of the lower piedmont and the coppice dunes of the Tularosa Basin. Stands are at the northern and southern edge of the coppice dune field (MU1).

Fort Bliss Vegetation Map Unit Description — No.: 3

Plains Sandscrub
Sand Sagebrush/Mesa Dropseed

Major Community Types

CT 1: sand sagebrush/mesa dropseed	***Artemisia filifolia/Sporobolus flexuosus***
CT 2:	
CT 3:	

Inclusions

Incl 1: sand sagebrush/bush muhly	***Artemisia filifolia/Muhlenbergia porteri***
Incl 2: sand sagebrush/black grama	***Artemisia filifolia/Bouteloua eriopoda***
Incl 3: sand sagebrush/sparse undergrowth	***Artemisia filifolia/Sparse***

Description

Plains-Mesa Sandscrub occurs on variously located sandsheets on Fort Bliss. The largest sandsheet is in the Tularosa Basin, and the Sand Sagebrush/Mesa Dropseed community dominates the map unit at 75% in this locale. Sand Sagebrush/Bush Muhly and Sand Sagebrush/Sparse stands are intermixed on the sandsheet and, together, comprise about 18% of the map unit. The remainder of the map unit is composed of small inclusions of community types on the basin sandy plains such as the Rosemary Mint Series (3%) and the Sandsage/Alkali Sacaton type (2%). Small communities particular to sandsheets on Otero Mesa (Sandsage/Black Grama), and sandsheets of the Sacramento Mountain foothills (Littleleaf sumac/Indian Ricegrass) make up about 2% of the map unit,

Fort Bliss Vegetation Map Unit Description — No.: 4

Basin Desert Shrubland
Honey Mesquite/Alkali Sacaton

Major Community Types

CT 1:	**honey mesquite/alkali sacaton**	***Prosopis glandulosa/Sporobolus airoides***
CT 2:		
CT 3:		

Inclusions

Incl 1:	**fourwing saltbush/burrograss**	***Atriplex canescens/Scleropogon brevifolius***
Incl 2:	**fourwing saltbush/sparse undergrowth**	***Atriplex canescens/Sparse***
Incl 3:		

Description

About 90% of this Basin Desert Shrubland is dominated by Honey Mesquite/Alkali Sacaton stands in broad clayey depressions at the northern edge of the coppice dunefield in the basin bottom. Sparsely vegetated Four-wing Saltbush dominated communities are also in this area and make up the remainder of the map unit.

Fort Bliss Vegetation Map Unit Description — No.: 5

Basin/Lowland Desert Shrubland
Tarbush with Tobosa, Sacaton and Burro Grasses

Major Community Types

CT 1: tarbush/tobosagrass	***Flourensia cernua/Hilaria mutica***
CT 2: tarbush/burrograss	***Flourensia cernua/Scleropogon brevifolius***
CT 3: tarbush/alkali sacaton	***Flourensia cernua/Sporobolus airoides***

Inclusions

Incl 1: tobosagrass-burrograss	***Hilaria mutica-Scleropogon brevifolius***
Incl 2: tarbush/sparse undergrowth	***Flourensia cernua/Sparse***
Incl 3: tarbush/blue grama	***Flourensia cernua/Bouteloua gracilis***

Description

This Basin/Lowland Desert Shrubland is made up of bottomland Tarbush communities. Tarbush/Tobosagrass, Tarbush/Burrograss and Tarbush/Sparse communities with Creosotebush phases dominate the unit equally, and combined, make up about 65% of the area. These communities are on silty alluvial fan toe slopes and bottomlands on northern Otero Mesa and below Otero Mesa in the basin. Tobosagrass communities with Creosotebush phases and Sacaton swales are inclusions within this map unit (14%). The remainder of the map unit is comprised of Tarbush/Alkali Sacaton and Fourwing Saltbush communities on heavy clay depressions near the northern extent of the Tularosa Basin on Fort Bliss.

Fort Bliss Vegetation Map Unit Description No.: 6

Lower Piedmont Desert Shrubland
Creosotebush and Tarbush with Bush Muhly

Major Community Types

CT 1:	**creosotebush/bush muhly**	***Larrea tridentata/Muhlenbergia porteri***
CT 2:	**tarbush/bush muhly**	***Flourensia cernua/Muhlenbergia porteri***
CT 3:	**creosotebush/sparse undergrowth**	***Larrea tridentata/Sparse***

Inclusions

Incl 1:	**creosotebush/mesa dropseed**	***Larrea tridentata/Sporobolus flexuosus***
Incl 2:	**honey mesquite/bush muhly**	***Prosopis glandulosa/Muhlenbergia porteri***
Incl 3:	**tarbush/sparse undergrowth**	***Flourensia cernua/Sparse***

Description

This Desert Shrubland is dominated by Creosotebush/Bush Muhly (48% cover), Tarbush/Bush Muhly (26% cover) and Creosotebush/Sparse (14% cover) community types. These types occur on heavy depositional soils of the lower toe-slopes and basin bottom. Tarbush/Sparse is a common inclusion in this same area. Honey Mesquite/Bush Muhly and Creosotebush/Mesa Dropseed are also common inclusions, but occur on heavy soils mantled by sand near the basin bottom sandsheet.

Fort Bliss Vegetation Map Unit Description No.: 7

Lower Piedmont Desert Shrubland
Creosotebush with Honey Mesquite

Major Community Types

CT 1:	**creosotebush/sparse undergrowth, honey mesquite**	***Larrea tridentata/Sparse,Prosopis glandulosa phase***
CT 2:	**honey mesquite/tobosagrass**	***Prosopis glandulosa/Hilaria mutica***
CT 3:		

Inclusions

Incl 1:

Incl 2:

Incl 3:

Description

This Desert Shrubland is dominated by Creosotebush/Sparse on the eastern piedmont of the Organ Mountains. It makes up about 76% of the map unit and occurs on gravelly to silty soils on moderate to gently graded slopes. The remainder of this shrubland is comprised of Honey Mesquite/Tobosagrass which occurs on depositional alluvial plains.

Fort Bliss Vegetation Map Unit Description — No.: 8

Upper Piedmont Desert Shrubland
Creosotebush/Bush Muhly (Mariola)

Major Community Types

CT 1:	**creosotebush/bush muhly**	***Larrea tridentata/Muhlenbergia porteri***
CT 2:	**creosotebush/sparse undergrowth**	***Larrea tridentata/Sparse***
CT 3:	**creosotebush-mariola**	***Larrea tridentata-Parthenium incanum***

Inclusions

Incl 1:	**honey mesquite/bush muhly**	***Prosopis glandulosa/Muhlenbergia porteri***
Incl 2:	**viscid acacia/bush muhly**	***Acacia neovernicosa/Muhlenbergia porteri***
Incl 3:	**creosotebush/tobosagrass**	***Larrea tridentata/Hilaria mutica***

Description

This Desert Shrubland is dominated by Creosotebush/Bush Muhly (47%), Creosotebush/Sparse (21%) and Creosotebush/Mariola (15%) community types. They occur on gravelly soils of the upper piedmont and foothills of the Sacramento Mountains. The Creosotebush/Bush Muhly stands on the upper piedmont tend to have bush muhly between as well as under the shrubs, and a higher diversity overall than the same type on the silty depositional soils below (see MU6). Viscid Acacia/Bush Muhly and Honey Mesquite/Bush Muhly are inclusions near the transition between piedmont and basin bottom.

Fort Bliss Vegetation Map Unit Description — No.: 9

Foothill Desert Shrubland
Viscid Acacia

Major Community Types

CT 1: viscid acacia/sideoats grama	***Acacia neovernicosa/Bouteloua curtipendula***
CT 2: viscid acacia-mariola	***Acacia neovernicosa-Parthenium incanum***
CT 3: viscid acacia/black grama	***Acacia neovernicosa/Bouteloua eriopoda***

Inclusions

Incl 1: viscid acacia-ocotillo	***Acacia neovernicosa-Fouquieria splendens***
Incl 2: viscid acacia/sparse undergrowth	***Acacia neovernicosa/Sparse***
Incl 3: lechuguilla-viscid acacia	***Agave lechuguilla-Acacia neovernicosa***

Description

This Desert Shrubland is comprised mostly of Viscid Acacia community types on gravelly slopes of foothills, mesa scarps and upper piedmont. Soils are generally shallow. Viscid Acacia/Sideoats is the dominant community, covering about 41% of the area. Viscid Acacia/Mariola and Viscid Acacia/Black Grama contribute about 18% each to the total map unit, and are located at slightly lower elevations than the Sideoats type. Viscid Acacia/Sparse and Viscid Acacia/Ocotillo are inclusions that are interspersed in the other Viscid Acacia stands.

Fort Bliss Vegetation Map Unit Description — No.: 10

Foothill Desert Shrubland
Mimosa/Sideoats Grama

Major Community Types

CT 1: /sideoats grama	***Mimosa aculeaticarpa/Bouteloua curtipendula***
CT 2:	
CT 3:	

Inclusions

Incl 1: shrub live oak-true mountain mahogany	***Quercus turbinella/Cercocarpus montanus***
Incl 2: shrub live oak/sideoats grama	***Quercus turbinella/Bouteloua curtipendula***
Incl 3: /tanglehead	***Mimosa aculeaticarpa/Heteropogon contortus***

Description

About 93% of this Desert Shrubland is dominated by Mimosa/Sideoats on low to mid-elevation gravelly slopes of east-side canyons of the Organ Mountains. Smaller inclusions include Shrub Liveoak/Sideoats, Shrub Liveoak/Mountain Mahogany and Mimosa/Tanglehead.

Fort Bliss Vegetation Map Unit Description — No.: 11

Foothill Desert Shrubland
Ocotillo-Mariola

Major Community Types

CT 1:	**ocotillo-mariola**	***Fouquieria splendens-Parthenium incanum***
CT 2:	**ocotillo/sparse undergrowth**	***Fouquieria splendens/Sparse***
CT 3:	**ocotillo-plume tiquilia**	***Fouquieria splendens-Tiquilia greggii***

Inclusions

Incl 1:

Incl 2:

Incl 3:

Description

This Desert Shrubland is dominated by Ocotillo/Mariola (about 45% of the map unit area) on rocky foothills of the Sacramento, Organ and Franklin Mountains. This community type may occur on any aspect, and covers slopes, benches and ridges. Common inclusions are Ocotillo/Sparse (6%) and Ocotillo/Plume Tiquilia (2%), the latter being primarily restricted to the Huecos.

Fort Bliss Vegetation Map Unit Description — No.: 12

Foothill Desert Shrubland
Lechuguilla/Sideoats Grama

Major Community Types

CT 1:	**lechuguilla/sideoats grama**	***Agave lechuguilla/Bouteloua curtipendula***
CT 2:	**lechuguilla-mariola**	***Agave lechuguilla-Parthenium incanum***
CT 3:	**lechuguilla/black grama**	***Agave lechugilla/Bouteloua eriopoda***

Inclusions

Incl 1:

Incl 2:

Incl 3:

Description

This Foothill Desert Shrubland is dominated by Lechugilla/Sideoats which occurs on all aspects of the Hueco Mountains and Unnamed Hills, comprising about 80% of the map unit area. Lechugilla/Black Grama and Lechugilla/Mariola are common inclusions that make up the remainder of this map unit.

Fort Bliss Vegetation Map Unit Description — No.: 13

Sandy Plains Desert Grassland
Mesa Dropseed/Soaptree Yucca

Major Community Types

CT 1: mesa dropseed/soaptree yucca — ***Sporobolus flexuosus/Yucca elata***
CT 2: mesa dropseed-spike dropseed — ***Sporobolus flexuosus-Sporobolus contractus***
CT 3:

Inclusions

Incl 1:

Incl 2:

Incl 3:

Description

This Desert Grassland is dominated by Mesa Dropseed/Soaptree Yucca (72% of the map unit area) and Mesa Dropseed-Spike Dropseed. These Community Types occur on the basin sandsheet. Often, stands are in slight depressions that have been created by downdropping along north-south trending fault zones. This grassland mostly occurs south of McGregor Range Camp and also east of the Jarilla Mountains.

Fort Bliss Vegetation Map Unit Description — No.: 14

Basin/Lowland Desert Grassland
Tobosagrass and Alkali Sacaton

Major Community Types

CT 1: tobosagrass-blue grama	***Hilaria mutica-Bouteloua gracilis***
CT 2: tobosagrass/monotypic stand	***Hilaria mutica/Monotypic***
CT 3: tobosagrass-alkali sacaton	***Hilaria mutica-Sporobolus airoides***

Inclusions

Incl 1: arroyo/arroyo	***Arroyo/Arroyo***
Incl 2: tobosagrass-burrograss	***Hilaria mutica-Scleropogon brevifolius***
Incl 3: alkali sacaton-obtuse panicgrass	***Sporobolus airoides-Panicum obtusum***

Description

This Lowland Desert Grassland is comprised of communities that occur on heavy depositional soils of flats, bottomlands and swales. These areas are usually associated with drainages and may be located on Otero Mesa or the Sacramento and Organ piedmonts. The dominant Community Types are Tobosagrass/Blue Grama and Tobosa Grass/Monotypic Community Types, each of which contributes about 25% to the total map unit area. Common inclusions are Tobosagrass/Burrograss (11%) on slightly drier or disturbed sites and Vine Mesquite/Monotypic (2%). Unclassified Southwestern Riparian communities of narrow, rocky drainages are included in this map unit (15%).

Fort Bliss Vegetation Map Unit Description   No.: 15

Basin/Lowland Desert Grassland
Burrograss

Major Community Types

CT 1: burrograss/monotypic stand   ***Scleropogon brevifolius/Monotypic***
CT 2:
CT 3:

Inclusions

Incl 1:

Incl 2:

Incl 3:

Description

This Lowland Desert Grassland is composed entirely of the Burrograss/Monotypic Community Type. It is located on depositional soils of drainages on Otero Mesa and on broad alluvial depressions in the Tularosa Basin. Vegetation cover may be very sparse.

Fort Bliss Vegetation Map Unit Description — No.: 16

Upper Piedmont Desert Grassland
Black Grama Grasslands

Major Community Types

CT 1: black grama/Torrey's jointfir *Bouteloua eriopoda/Ephedra torreyana*
CT 2:
CT 3:

Inclusions

Incl 1:
Incl 2:
Incl 3:

Description

This Desert Grassland is co-dominated by Black Grama/Torrey's Jointfir and Black Grama/Honey Mesquite Community Types. These are on coarse, gravelly upper piedmont of the Organ Mountains.

Fort Bliss Vegetation Map Unit Description   No.: 17

Foothills/Piedmont Desert Grassland
Black Grama-Sideoats Grama (Creosotebush)

Major Community Types

CT 1:	**black grama-sideoats grama**	***Bouteloua eriopoda-Bouteloua curtipendula***
CT 2:	**black grama-sideoats grama/soaptree yucca**	***Bouteloua eriopoda-Bouteloua curtipendula/Yucca elata***
CT 3:	**creosotebush/black grama**	***Larrea tridentata/Bouteloua eriopoda***

Inclusions

Incl 1:	**black grama-sideoats grama/common sotol**	***Bouteloua eriopoda-Bouteloua curtipendula/Dasylirion***
Incl 2:	**black grama/mariola**	***Bouteloua eriopoda/Parthenium incanum***
Incl 3:	**tarbush/black grama**	***Flourensia cernua/Bouteloua eriopoda***

Description

This Foothill/Piedmont Grassland is on the gravelly footslopes and piedmont of the Sacramento, Hueco and Franklin Mountains. Creosotebush/Black Grama, Black Grama/Sideoats and Black Grama-Soaptree Yucca Community Types each contribute about 20% to the total map unit area. Black Grama/Mariola and Black Grama/Sotol are common inclusions on the lower, rockier slopes and make up 15% and 5% of the map unit area, respectively.

Fort Bliss Vegetation Map Unit Description — No.: 18

Foothills Grassland
SideoatsGrama/Sacahista (Curlyleaf Muhly)

Major Community Types

CT 1: sideoats grama/sacahuista	***Bouteloua curtipendula/Nolina microcarpa***
CT 2: curlyleaf muhly-sideoats grama	***Muhlenbergia setifolia-Bouteloua curtipendula***
CT 3: sideoats grama/monotypic stand	***Bouteloua curtipendula/Monotype***

Inclusions

Incl 1: hairy grama-sideoats grama	***Bouteloua hirsuta-Bouteloua curtipendula***
Incl 2: curlyleaf muhly-hairy grama	***Muhlenbergia setifolia-Bouteloua hirsuta***
Incl 3:	

Description

This Foothills Grassland is dominated by Sideoats/Sacahuista (48% of the map unit area) and Curlyleaf Muhly-Sideoats (19%) Community Types. These occur predominantly on gravelly and rocky slopes near Otero Mesa Escarpment and on canyon walls of the Escarpment, although some stands may also occur on the upper piedmont of Otero Mesa and the Hueco Mountains. Curlyleaf Muhly-Hairy Grama (8%) and Hairy Grama-Sideoats (6%) are inclusions found on the gravelly footslopes of the Sacramento Mountains. Sideoats/Monotypic (11%) is an inclusion on silty soils of low tablelands below Otero Mesa.

Fort Bliss Vegetation Map Unit Description — No.: 19

Mesa Grassland
Blue Grama-Alkali Sacaton (Soaptree Yucca)

Major Community Types

CT 1:	**blue grama-alkali sacaton**	***Bouteloua gracilis-Sporobolus airoides***
CT 2:	**blue grama/soaptree yucca**	***Bouteloua gracilis/Yucca elata***
CT 3:	**blue grama-purple threeawn**	***Bouteloua gracilis-Aristida purpurea***

Inclusions

Incl 1:	**blue grama/banana yucca**	***Bouteloua gracilis/Yucca baccata***
Incl 2:	**hairy grama-blue grama**	***Bouteloua hirsuta-Bouteloua gracilis***
Incl 3:		

Description

The Blue Grama-Alkali Sacaton Community Type dominates this Mesa Grassland at around 44% cover. It occurs on silty-clay soils near the Sacramento Foothills, and tends to be located in slight depressions near drainages originating in the Foothills. Blue Grama/Soaptree Yucca is in similar positions of the landscape and makes up about 25% of the map unit. The Hairy Grama/Blue Grama Type is an inclusion (10%) that occurs near the margins of Black Grama grasslands in slight depressions.

Fort Bliss Vegetation Map Unit Description   No.: 20

Mesa Grassland
Black Grama-Blue Grama (Soaptree Yucca)

Major Community Types

CT 1: black grama-blue grama	***Bouteloua eriopoda-Bouteloua gracilis***
CT 2: black grama-blue grama/soaptree yucca	***Bouteloua eriopoda-Bouteloua gracilis/Yucca elata***
CT 3: black grama/soaptree yucca	***Bouteloua eriopoda/Yucca elata***

Inclusions

Incl 1: black grama-purple threeawn	***Bouteloua eriopoda-Aristida purpurea***
Incl 2: black grama/banana yucca	***Bouteloua eriopoda/Yucca baccata***
Incl 3: black grama-ear muhly	***Bouteloua eriopoda-Muhlenbergia arenacea***

Description

The Black Grama-Blue Grama Community Type dominates this Mesa Grassland at 33% cover. It occurs in extensive stands on fine silty soils of the rolling plains of Otero Mesa and low tablelands beneath Otero Mesa. Black Grama-Blue Grama/Soaptree Yucca is interspersed within this dominant type and comprises about 17% of the map unit. Black Grama-Sand Muhly is a significant community type at about 18% cover on sandier soils of the tablelands. Common inclusions are Black Grama/Soaptree Yucca and Black Grama-Purple Three-awn on sandy or disturbed sites. Black Grama-Ear Muhly is a small inclusion occurring in shallow depressions within the grasslands.

Fort Bliss Vegetation Map Unit Description — No.: 21

Mesa Grassland
Black Grama-Blue Grama (Banana yucca)

Major Community Types

CT 1: black grama-blue grama, banana yucca ph. — ***Bouteloua eriopoda-Bouteloua gracilis, Yucca baccata***
CT 2: black grama/banana yucca — ***Bouteloua eriopoda/Yucca baccata***
CT 3:

Inclusions

Incl 1:

Incl 2: black grama-blue grama — ***Bouteloua eriopoda-Bouteloua gracilis***

Incl 3:

Description

This Mesa Grassland is located predominantly on southern Otero Mesa where soils are shallow and rocky. Black Grama-Blue Grama/Banana Yucca is the dominant Community Type (87% of total cover) and is extensive in this area. The Black Grama/Banana Yucca Type comprises about 11% of the map unit and is located primarily near the Mesa Escarpment. Black Grama-Blue Grama is an inclusion on finer, deeper soils.

Fort Bliss Vegetation Map Unit Description No.: 22

Mesa/Foothills Grassland
New Mexico Needlegrass-Mixed Grama Grass

Major Community Types

CT 1:	**New Mexico needlegrass-sideoats grama**	***Stipa neomexicana-Bouteloua curtipendula***
CT 2:	**New Mexico needlegrass-black grama**	***Stipa neomexicana-Bouteloua eriopoda***
CT 3:	**New Mexico needlegrass-hairy grama**	***Stipa neomexicana-Bouteloua hirsuta***

Inclusions

Incl 1:	**sideoats grama/banana yucca**	***Bouteloua curtipendula/Yucca baccata***
Incl 2:	**blue grama-sideoats grama**	***Bouteloua gracilis-Bouteloua curtipendula***
Incl 3:		

Description

This Mesa-Foothills Grassland occurs on rocky ridges of slopes and rises of southern Otero Mesa, and consists mostly of New Mexico Needlegrass communities. New Mexico Needlegrass-Sideoats, New Mexico Needlegrass-Black Grama and New Mexico Needlegrass-Hairy Grama each contribute about 30% to the total map unit area. Sideoats/Banana Yucca is a minor inclusion (3%) in similar positions in the landscape. Blue Grama-Sideoats is an inclusion occurring in shallow, rocky depressions.

Fort Bliss Vegetation Map Unit Description No.: 23

Foothills Grassland
Sideoats Grama, Curlyleaf Muhly and Mixed Shrubs

Major Community Types

CT 1: sideoats grama/skeletonleaf goldeneye	***Bouteloua curtipendula/Viguiera stenoloba***
CT 2: sideoats grama/ocotillo	***Bouteloua curtipendula/Fouquieria splendens***
CT 3: sideoats grama/common sotol	***Bouteloua curtipendula/Dasylirion wheeleri***

Inclusions

Incl 1: curlyleaf muhly-black grama	***Muhlenbergia setifolia-Bouteloua eriopoda***
Incl 2: New Mexico needlegrass-curlyleaf muhly	***Stipa neomexicana-Muhlenbergia setifolia***
Incl 3: hairy grama-sideoats grama	***Bouteloua hirsuta-Bouteloua curtipendula***

Description

This Foothills Grassland is dominated by Sideoats/Skeletonleaf Goldeneye (37% of the map unit area) and Sideoats/Sotol (9%) Community Types. Stands are located on the Otero Mesa Escarpment and rocky scarp slopes of the Sacramento and Hueco Mountains. Sideoats/Ocotillo (22%) occurs more frequently in the Huecos on all slope aspects. Inclusions are Curlyleaf Muhly-New Mexico Needlegrass, Hairy Grama-Sideoats and Curlyleaf Muhly-Black Grama on similar positions in the landscape.

Fort Bliss Vegetation Map Unit Description — No.: 24

Foothills Grassland
Sideoats Grama/Sotol and Hairy Grama/Sotol

Major Community Types

CT 1: sideoats grama/common sotol	***Bouteloua curtipendula/Dasylirion wheeleri***
CT 2: hairy grama/common sotol	***Bouteloua hirsuta/Dasylirion wheeleri***
CT 3: bullgrass-sideoats grama	***Muhlenbergia emersleyi-Bouteloua curtipendula***

Inclusions

Incl 1: bullgrass/common sotol	***Muhlenbergia emersleyi/Dasylirion wheeleri***
Incl 2: sideoats grama-Single threeawn	***Bouteloua curtipendula-Aristida orcuttiana***
Incl 3:	

Description

This Foothills Grassland is located on low to mid-elevation rocky slope of canyons in the Organ Mountains. The Sideoats-Bullgrass type dominates on north-facing slopes (41% of the map unit area) with Sideoats/Sotol (35%) and Hairy Grama/Sotol (23%) on south-facing slopes. Minor inclusions of Sideoats-Single Three-awn and Bullgrass/Sotol are in small patches on the slopes.

Fort Bliss Vegetation Map Unit Description — No.: 25

Mountane Riparian
Boxelder, Velvet Ash, Willow and Apacheplume

Major Community Types

CT 1: black grama/Apacheplume	***Bouteloua eriopoda/Fallugia paradoxa***
CT 2: coyote willow/deergrass	***Salix exigua/Muhlenbergia rigens***
CT 3: box elder-velvet ash	***Acer negundo-Fraxinus velutina***

Inclusions

Incl 1: coyote willow/bulb panicgrass	***Salix exigua/Panicum bulbosum***
Incl 2:	
Incl 3: Gambel's oak/whortleleaf snowberry	***Quercus gambelii/Symphoricarpos oreophilus***

Description

This Montane Riparian community occurs near mountain valley drainages of the Organ Mountains. Black Grama/Apache Plume is the dominant Community Type (about 45% of the map unit area) and occurs on slopes above drainages. Coyote Willow/Deergrass (26%) and Boxelder-Velvet Ash (21%) are in the drainages. Coyote Willow/Bulbous Panicum and Gambels Oak/Whortleleaf Snowberry are small inclusions in and near the drainages.

Fort Bliss Vegetation Map Unit Description

No.: 26

Montane Shrubland
Mountain Mahogany/Mixed Grass

Major Community Types

CT 1:	**true mountain mahogany/curlyleaf muhly**	***Cercocarpus montanus/Muhlenbergia setifolia***
CT 2:	**true mountain mahogany/bullgrass**	***Cercocarpus montanus/Muhlenbergia emersleyi***
CT 3:	**true mountain mahogany/New Mexico needlegrass**	***Cercocarpus montanus/Stipa neomexicana***

Inclusions

Incl 1:	**true mountain mahogany/New Mexico muhly**	***Cercocarpus montanus/Muhlenbergia pauciflora***
Incl 2:	**true mountain mahogany-desert ceanothus**	***Cercocarpus montanus-Ceanothus greggii***
Incl 3:	**true mountain mahogany/sideoats grama**	***Cercocarpus montanus/Bouteloua curtipendula***

Description

This Montane Shrubland occurs predominantly on rocky south facing slopes at mid-elevations in the Organ and Sacramento Mountains. It is dominated by Mountain Mahogany Community Types. Mountain Mahogany/Curlyleaf Muhly, Mountain Mahogany/Bullgrass and Mountain Mahogany/New Mexico Needlegrass are dominant types, each comprising about 20% of the map unit. These communities occur mostly in the Sacramentos and have open shrub canopies with dense herbaceous understories. Mountain Mahogany/New Mexico Muhly and Mountain Mahogany/Sideoats are inclusions that occur predominantly in the Organs and have moderately closed shrub canopies and sparse herbaceous understories. Mountain Mahogany-Desert Ceanothus is a common inclusion (13%) in all areas.

Fort Bliss Vegetation Map Unit Description — No.: 27

Montane Shrubland
Gambel's Oak-Whortleleaf Snowberry

Major Community Types

CT 1: Gambel's oak/whortleleaf snowberry *Quercus gambelii/Symphoricarpos oreophilus*
CT 2:
CT 3:

Inclusions

Incl 1:

Incl 2:

Incl 3:

Description

This Montane Shrubland is composed entirely of the Gambels Oak-Whortleleaf Snowberry Community Type. It occurs in dense stands on north-facing slopes at mid to high elevations in the Organ Mountains.

Fort Bliss Vegetation Map Unit Description — No.: 28

Woodland
Oneseed Juniper Mixed Grass

Major Community Types

CT 1:	**oneseed juniper/curlyleaf muhly**	***Juniperus monosperma/Muhlenbergia setifolia***
CT 2:	**oneseed juniper/**	***Juniperus monosperma/Quercus spp.***
CT 3:	**alligator juniper/hairy grama**	***Juniperus deppeana/Bouteloua hirsuta***

Inclusions

Incl 1:	**alligator juniper/sideoats grama**	***Juniperus deppeana/Bouteloua curtipendula***
Incl 2:	**oneseed juniper/hairy grama**	***Juniperus monosperma/Bouteloua hirsuta***
Incl 3:		

Description

This Rocky Mountain Woodland occurs on smooth rocky and gravelly slopes at moderately high elevations of the Organ and Sacramento Mountains. Alligator Juniper/Curlyleaf Muhly is the dominant community type at about 48% of the map unit area. Alligator Juniper/Hairy Grama (6%) and One-seed Juniper-Oak (21%) are also prevalent. Common inclusions are Oneseed Juniper/Hairy Grama and Alligator Juniper/Sideoats in similar landscape positions.

Fort Bliss Vegetation Map Unit Description No.: 29

Woodland
Pinyon Pine with Oak and Alligator Bark Juniper

Major Community Types

CT 1:	**pinyon pine-alligator juniper**	***Pinus edulis-Juniperus deppeana***
CT 2:	**pinyon pine/sideoats grama**	***Pinus edulis/Bouteloua curtipendula***
CT 3:	**pinyon pine-**	***Pinus edulis-Quercus pungens***

Inclusions

Incl 1:	**pinyon pine-gray oak**	***Pinus edulis-Quercus grisea***
Incl 2:	**pinyon pine/Scribner's needlegrass**	***Pinus edulis/Stipa scribneri***
Incl 3:	**pinyon pine/prairie Junegrass**	***Pinus edulis/Koeleria macrantha***

Description

Pinon Pine communities dominate this Rocky Mountain Woodland on high elevation upland slopes of the Sacramento and Organ Mountains. Soils are rocky, but well developed and are often high in organic matter. Pinon Pine-Oneseed Juniper is the dominant Community Type at 76% of the map unit area, and has a nearly closed tree canopy. Pinon Pine-Sandpaper Oak is intermixed in more open tree canopies and accounts for about 14% of the map unit. Pinon Pine/Scribner's Needlegrass, Pinon Pine-Grey Oak and Pinon Pine/Prairie Junegrass are minor inclusions.

Fort Bliss Vegetation Map Unit Description — No.: 30

Forest
Ponderosa Pine and Douglas-Fir

Major Community Types

CT 1: ponderosa pine/Gambel's oak	***Pinus ponderosa/Quercus gambelii***
CT 2: common Douglas-fir/Gambel's oak	***Pseudotsuga menziesii/Quercus gambelii***
CT 3: ponderosa pine/mountain muhly	***Pinus ponderosa/Muhlenbergia montana***

Inclusions

Incl 1: Gambel's oak/whortleleaf snowberry	***Quercus gambelii/Symphoricarpos oreophilus***
Incl 2: ponderosa pine/prairie Junegrass	***Pinus ponderosa/Koeleria macrantha***
Incl 3: ponderosa pine-gray oak	***Pinus ponderosa/Quercus grisea***

Description

This Rocky Mountain Forest occurs in the upper elevations of the Organ Mountains, generally on steep slopes. Ponderosa Pine/Gambel's Oak is the dominant Community Type (50% of map unit area). Douglas Fir-Gambel's Oak types occur just above or intermixed with the Ponderosa Pine stands, and contribute about 29% to the map unit area. Ponderosa Pine/Mountain Muhly (11%) is in more open areas. Small inclusions are Ponderosa Pine/Prairie Junegrass, Ponderosa Pine-Grey Oak and Gambel's Oak-Whortleleaf Snowberry.

Fort Bliss Vegetation Map Unit Description   No.: 31

Piedmont Grassland (Disturbed)
Arizona Cottontop, Three-awn and Grama Grasses

Major Community Types

CT 1: streambed bristlegrass-Arizona cottontop ***Setaria leucopila-Digitaria californica***
CT 2:
CT 3:

Inclusions

Incl 1:

Incl 2:

Incl 3:

Description

This Disturbed Piedmont Grassland occurs on the piedmont east and west of Rattlesnake Ridge in the Organ Mountains. Disturbance seems to have been mostly caused by exploding ordnance. The map unit is composed entirely of the Streambed Bristlegrass/Arizona Cottontop community type, but there are patches of mesquite, creosotebush and tarbush as well.

Fort Bliss Vegetation Map Unit Description

No.: 32

Barren/Military
Rock, Barren Soil, Miltary Cantonment and Impact Areas

Major Community Types

CT 1: *Barren - Scarcely Vegetated*
CT 2:
CT 3:

Inclusions

Incl 1:
Incl 2:
Incl 3:

Description

This map unit was created to account for military cantonment sites, heavily impacted areas, rock and barren soil. The military sites and impact areas make up nearly 99% of the map unit.