DESERT ANALYSIS: THE QUEST FOR TRAINING AREAS

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ABSTRACT

For the United States Army to successfully operate on a global scale, today's troops and their equipment must be capable of accomplishing any mission in all possible environments; cold or hot, wet or dry, and every possible combination of terrain. This requirement challenges the Army's equipment, people, and training programs. To prepare for this full spectrum of operations, the Army develops and tests its equipment under extreme environmental conditions to assure that America's soldiers have the best that science and technology can provide. Further, units conduct training in a realistic manner and in environments that simulate natural settings. And finally, the Army must plan for contingencies on a worldwide scope.

This study is a scientific analysis of one of the three extreme environments important to a globally deployed Army; the desert environment. This work follows a successful examination of ideal locations of tropical environments for training of troops and testing of military systems. The tropical study was necessitated by the closure of all U.S. Army tropical testing and training facilities, which had been located in the Republic of Panama until 1999. In the process of searching for a replacement for the lost tropical testing and training facilities, the Army and its natural environment testing activity, Yuma Proving Ground, developed a better scientific understanding of how geographic analysis could enhance the Army's ability to test and train in natural environmental settings. The overall goal of this work is to expand our understanding of how to characterize the desert environment in ways that supports the needs of the Army, from testing, through training, to worldwide operational deployments.

1. Introduction

The United States Army must be trained and equipped to fight and win our Nation's wars, over any terrain and under the most extreme natural conditions. Recent experience finds America's troops engaged in conflicts in the mountains and deserts of Afghanistan, the deserts of Iraq, and the jungles of the Philippines. Yet today's Army is being asked to do much more. Peace keeping, humanitarian assistance and other types of Stability and Support Operations (SASO)[1] now require our soldiers to be ready to accomplish new missions on a global scale. This is clearly reflected in today's deployment data which shows the United States Army has troops stationed in more than 70 countries. The most important aspect of this issue is that the continued success of our Army in combat and in accomplishing SASO missions reaffirms that it remains the best trained and equipped Army in the world. Yet, substantial work remains to be carried out.

This study is part of a scientific analysis of one of the three extreme environments important to a globally deployed Army-- the desert environment. This work follows a successful examination of ideal locations of tropical environments for training and testing of military systems. The tropical study was necessitated by the closure of all U.S. Army tropical testing and training facilities, which had been located in the Republic of Panama until 1999, but were closed based on the Panama Canal Treaty. In the process of searching for a replacement for the lost tropical testing and training facilities, the Army and its natural environment testing activity, Yuma Proving Ground, developed a better understanding of how geographic analysis could enhance ability to test and train in natural environmental settings. Based on the success of the tropical studies, Yuma Proving Ground, as the Army managers for natural environmental testing, decided to conduct an examination of its desert testing resources. The goal here was not to replace existing facilities, but to better utilize existing resources to support the Army in its worldwide mission. Deserts are important biomes which severely challenge military operations. It must also be recognized that there is great variability in the lands typically characterized as deserts. These differences are the product of the physical processes that create and continue to influence the evolution of desert landscapes. Understanding more about the science of desert environments allows us to better test and train. This knowledge would also be important to military planners as they conduct mission analyses and develop plans for operations in desert regions.

The overall goal of this work is to expand the Army's understanding of the desert environment in order to better support the needs of the Army in meeting its worldwide mission. The information collected is focused on those militarily significant parameters that impact operations in deserts. These become the important parameters in selecting where and how to both test the Army's equipment and conduct effective desert training. The full scope of characterizing deserts is a broad issue and a significant undertaking, one best accomplished sequentially. The first phase of this effort is intended to characterize the differences between deserts in terms that are relevant to the military applications of testing, training, and operations. Deserts will be differentiated by parameters that characterize the climate, physical, and biological setting. Analyses of deserts will be produced on three scales: 1) the world extent of deserts will be characterized based on a set of summary climate

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1 SASO operations were formally called Military Operations Other Than War, or MOOTW - a term that still appears in some doctrinal manuals.

and physical parameters, 2) large tracts of training and testing lands will be described based on a more comprehensive set of these parameters, and finally 3) specific sites will be characterized by a set of climate, physical and biological parameters sufficient to fully define the testing and training capacity of an area. A primary product of this study will be a 'Desert Environmental Characterization Model'. Further, and recognizing that a model must be tested to ensure that it can describe actual conditions, the second product of this research will be a verification of the model by applying it to the US Army's primary desert test facility at Yuma Proving Ground (AZ), and the nation's premier armor and mechanized-infantry training area, the National Training Center at Ft Irwin (CA).

2. Goals and Objectives

The work described in this paper centers around four goals primarily focused on improving scientific understanding of deserts being used for testing:

i. Develop a model that characterizes deserts/arid environments using a set of scientific parameters.

ii. The second task is to apply the desert characterization model developed to the world's deserts to differentiate sub-categories that are significant from a military standpoint.

iii. This desert model is then applied to a geographic analysis of Yuma Proving Ground, to define any significant differences in test conditions available within the proving ground.

iv. The final task is to conduct a geographic mapping of the National Training Center at Ft Irwin based on the critical parameters identified in this work.

The procedure to be followed in this research was developed as a product of similar research conducted by a peer panel review (King and others, 1998), which analyzed locations for Army tropical testing and training. The problem requires a backward planning approach to reach a characterization of the desert testing environment. It starts by looking at the extent of deserts worldwide, recognizing that a wide variety exists. Measurable differences in desert environments must be characterized employing standard environmental parameters. These differences must be analyzed to determine if military operations are affected over the range of conditions that could exist in a desert or arid area.

Further, deserts are fragile environments when subjected to human activity, and military training and testing are certainly activities that can cause long-term change to a desert. These changes may make damaged areas less useful as testing or training sites. The Army lacks the scientific data needed to analyze which parameters are significant for military applications. This information could help decision makers to develop programs to better sustain training lands while providing realistic training opportunities.

3. Overview of the World's Deserts

One way to define a desert is as a geographic region with an arid climate which is characterized by a deficiency of precipitation (P) received on an annual basis relative to water loss by potential evaporation (ETP) from the ground and transpiration from plants. By this definition, about 1/3 of the earth's land surface is desert (Figure 1). The aridity that is a characteristic of all deserts creates a terrain with only sparse vegetation that, as a result, is covered by thin soils with a low organic content, which are highly erodible by wind and water. Aridity increases as the as the value of the ratio P/ETP decreases. Approximately 5 % of the earth is classified as extremely or hyper-arid, i.e., aridity < 0.05, while some 15% of the Earth's land area of 56 million square miles can be considered as arid, i.e. $P/ETP < 0.20$, and another 15% semi-arid, i.e. $0.20 > P/ETP > 0.50$ (UNESCO, 1979). In terms of the widely used Köppen climatic classification system (Köppen, 1923; Köppen and Geiger, 1930), the desert regions fall into the Group B Category of *Dry Climates*. Because annual water loss by evaporation exceeds the annual water gain by precipitation in these regions, there is no water surplus to maintain a groundwater supply and, therefore, no permanent surface water streams originate in the Group B desert regions. Meigs (1953) divided the arid regions of the world into three classes according to the amount of precipitation they received. Extremely arid lands are characterized by at least 12 consecutive months without rainfall, arid lands have less than 250 millimeters of annual rainfall, and semiarid lands have a mean annual precipitation of between 250 and 500 millimeters. Extremely arid and arid land are deserts, semi-arid lands are transition zones to more humid climates. As the figures indicate, the climates are further subdivided by the maximum annual temperature ranges and the seasonality of the small amounts of precipitation.

Another approach to classifying deserts of the world is to divide them into four distinct types based upon the cause of their aridity, which reflects their location relative to climate controls: **sub-tropical deserts, coastal deserts, cold-winter deserts,** and **polar deserts.** As shown in Figure 1, the great deserts of the Northern Hemisphere in Africa and the Middle East lie along the Tropic of Cancer (23^{o} N), whereas the deserts of North America and Central Asia lie at higher latitudes. In the Southern Hemisphere, the deserts of South America and Australia lie along the Tropic of Capricorn. These deserts are the result of worldwide air circulation patterns that develop semi-permanent belts of high pressure in the sub-tropics.

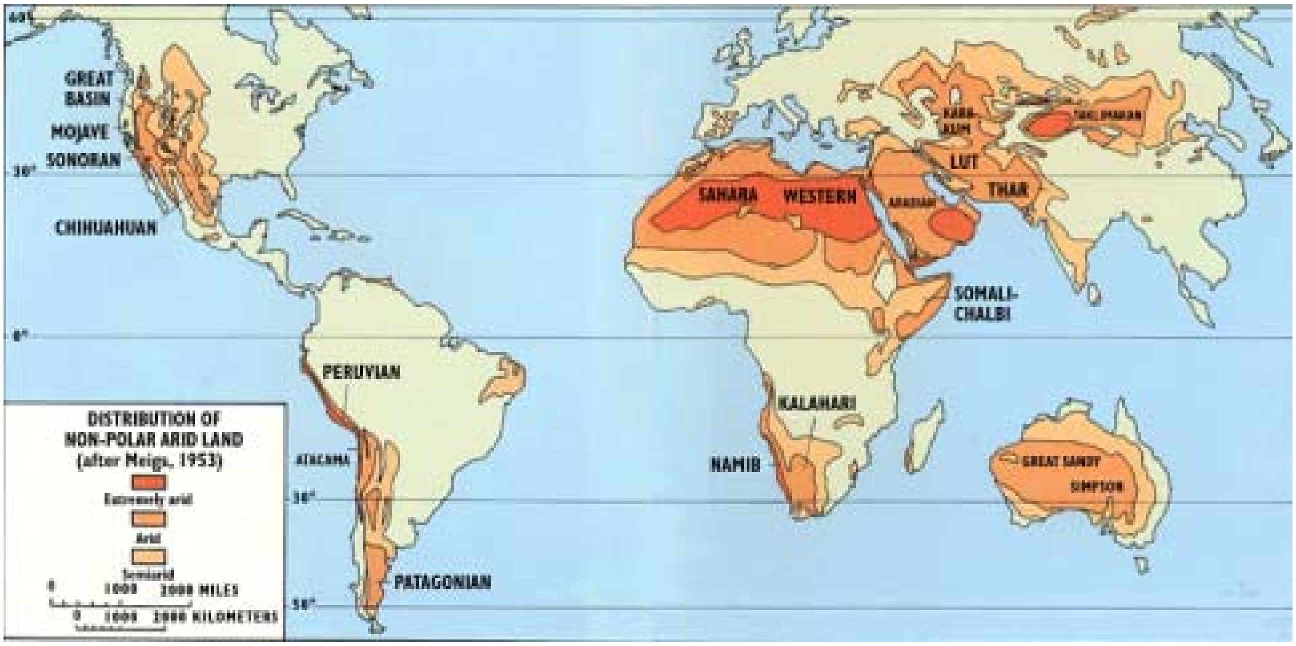

Figure.1. *Distribution of deserts around the world*
(from: http://pubs.usgs.gov/gip/deserts/what/world.html)

3.1 World-Scale Hot/Warm Deserts

Certainly, any classification of deserts must begin by examining precipitation and temperature. Figure 2 shows precipitation levels on a world-scale for the driest regions, regardless of temperatures. These data show that dry areas are bi-modally distributed between the very hot and the very cold regions of the world, with the hottest areas being the focus of this effort. It then follows that a second fundamental parameter to be considered in this desert classification process is an identification of the world's hottest regions, as presented in Figure 3. This figure is based on the average temperatures in the warmest month. There are numerous options for the parameter of temperature including warmest month, average daily temperatures, and others. An average of annual high daily temperatures generally summarizes all aspects of temperature by averaging seasonal and diurnal variations to show the overall impact of temperature on the environment (see Fig 4). This view shows that the warmest areas of the world are located in the regions receiving maximum insolation. However, the influence of maritime currents can reduce the impact of insolation, while the effects of continental heating can add to the overall heating, as with the Sahara and Australian deserts. A combination of low precipitation and high temperatures would yield a map similar to the Meigs (1953) aridity classification.

A third key variable describing the spatial distribution of deserts is natural vegetation or, as is often the case in deserts, the notable absence of vegetation. Figure 5 presents a coarse summary of the spatial distribution of desert landscapes based on vegetative cover. In this case, qualitative information about the type of vegetative land cover was correlated to latitudinal zones. These data are relatively imprecise, but the easiest interpretation is that the darker the color in Figure 5, the less abundant the vegetative cover.

As was discussed in the introduction, the focus of this work is to identify warm/hot deserts and provide a characterization of the environmental variability within these regions with regard to military operations and testing. A map of these areas can be constructed by intersecting high temperature, low precipitation, and desert landscape features of Figures 2 and 5. The goal here is to identify the extremes of temperature and dry conditions that provide the harshest challenges to military operations, training and testing of equipment. Figure 6, the intersection of high temperature, low precipitation and landscape parameters, represents those areas that are hotter, drier and have the most extreme desert landscapes. These areas represent the general locations for the greatest desert environmental challenges to troops and equipment. It only takes a glance to note that many countries of military significance lie within these areas, based on current world conditions.

This study used the hot/warm desert regions identified in Figure 6 as a delineation point. These hot, dry regions can be further demarcated by an examination of both scientific parameters derived from the data, combined within the context of military use for operations, training and testing. The following section describes the selection of critical variables used to differentiate these deserts in this context. It should be noted that it is not possible to draw world scale maps of these features because most of the physical and biological features are randomly scattered in a patchwork across the world's deserts, controlled by localized climate and geologic factors.

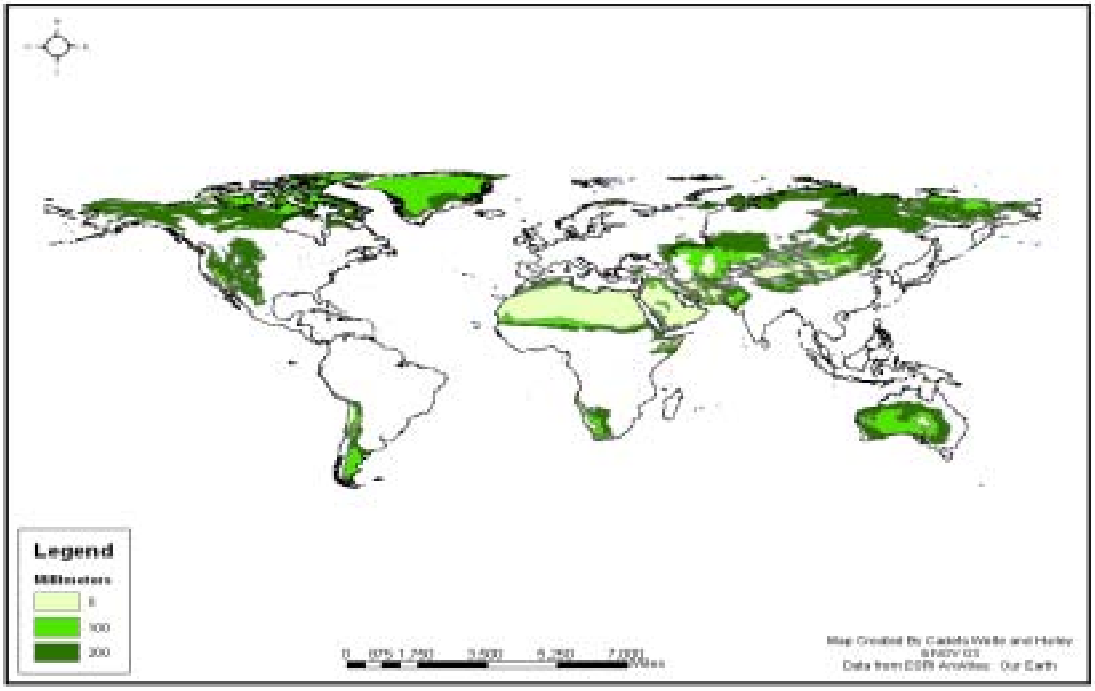

Figure 2. *Areas of Low Precipitation*

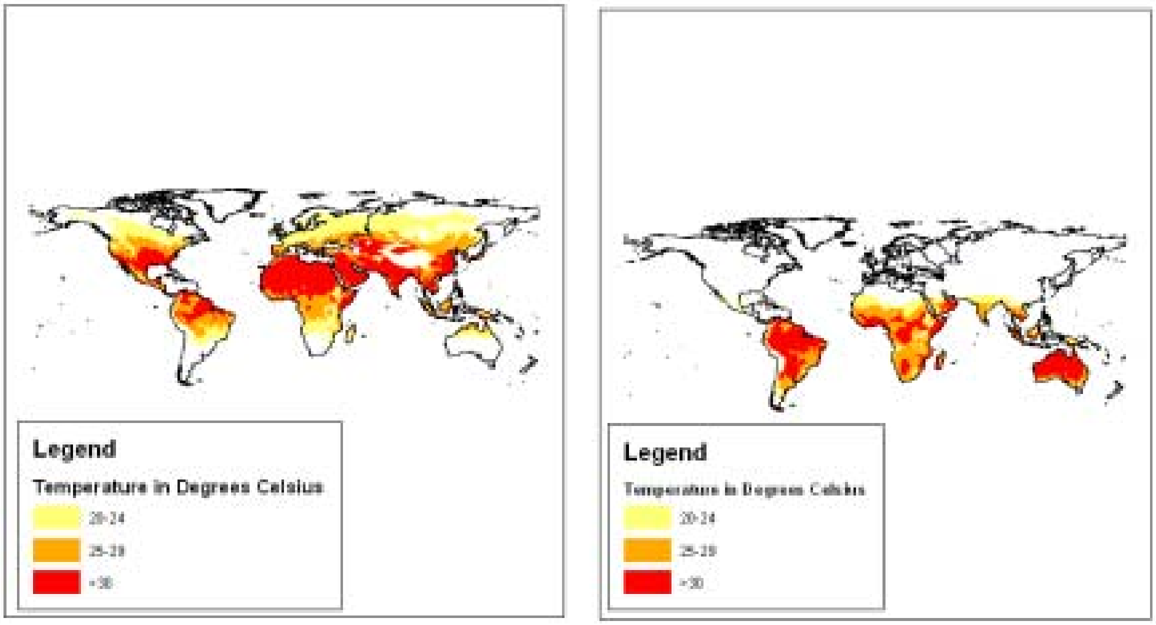

Figure 3. *Areas with the highest summer monthly temperatures. Map on the left depicts average temperature in July (corresponding with the northern hemisphere summer), and the map on the right depicts average January temperature (corresponding with southern hemisphere summer).*

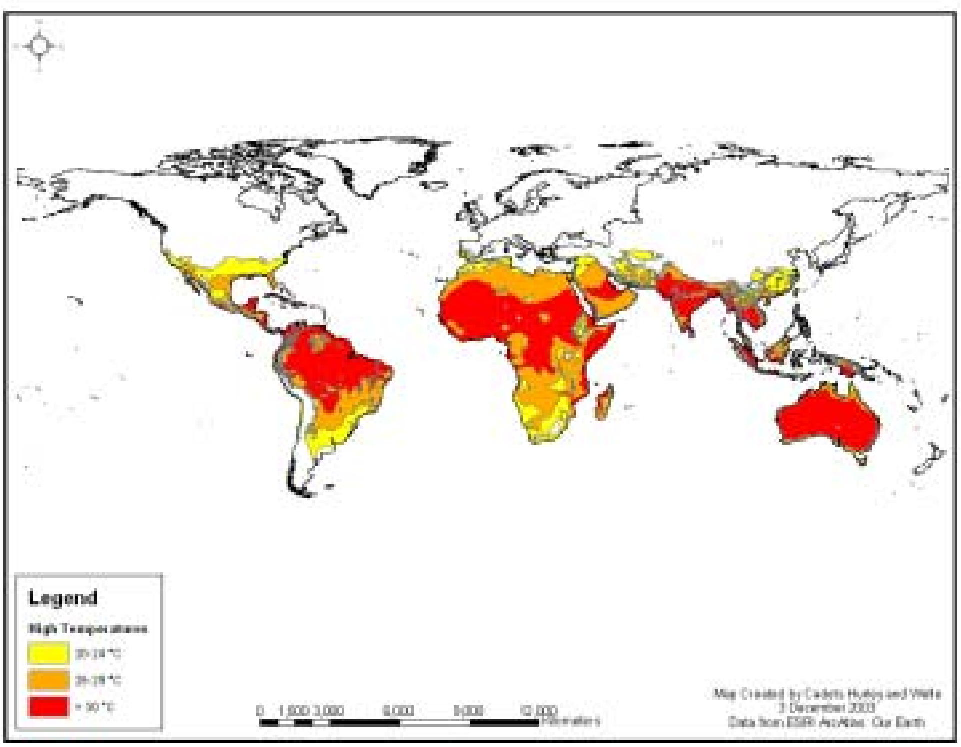

Figure 4. Areas with the highest annual average daily temperatures

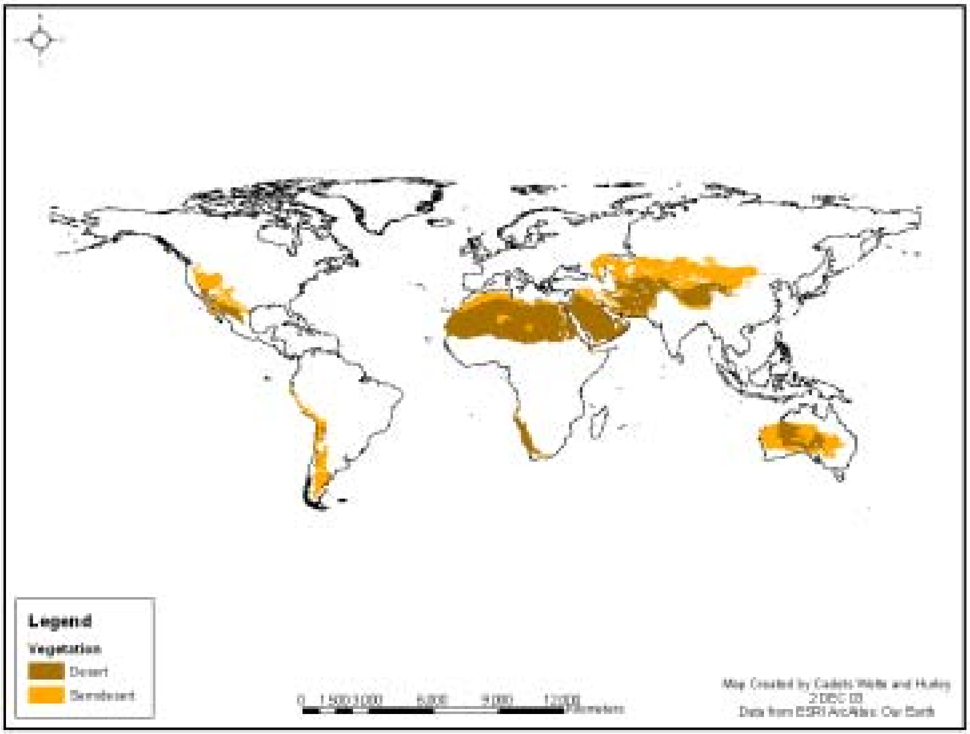

Figure 5. Areas of desert vegetation

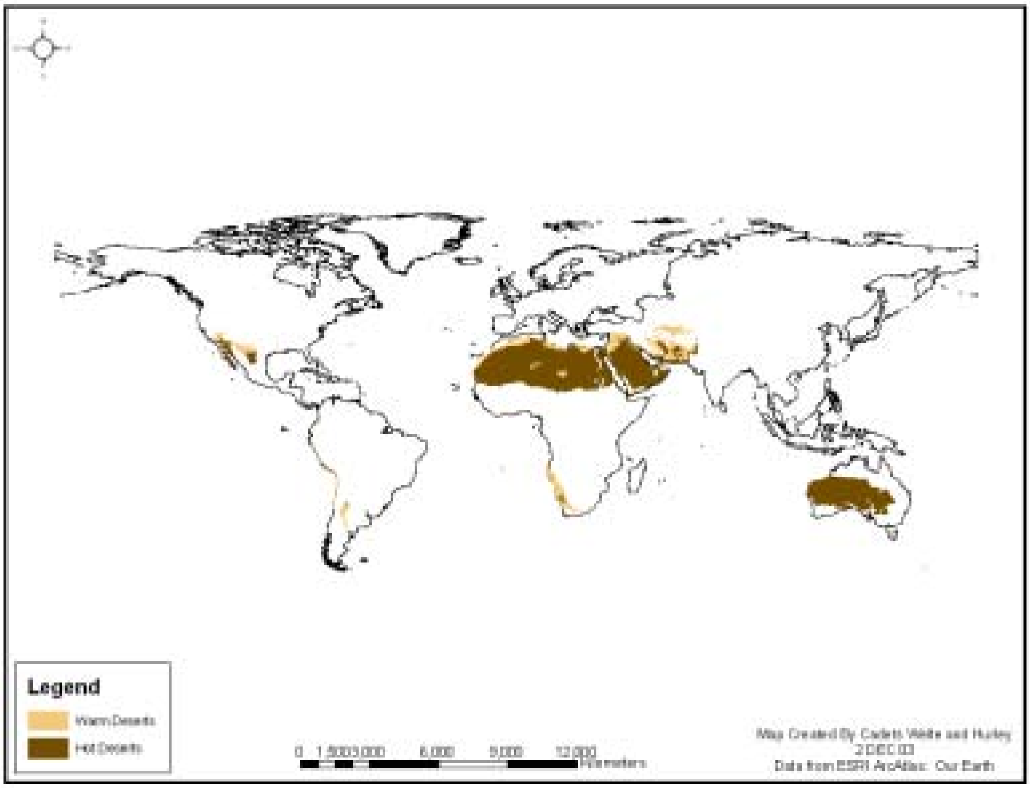

Figure 6. *World-scale location of hot/warm desert environments (intersection of Figs. 1- 4).*

4. Significant Physical and Biological Parameters.

Deserts vary significantly and dramatically in physiography, climate and vegetative cover. Often, variations in these parameters are highly localized, making it somewhat unproductive to delineate deserts on a world-scale using these detailed parameters. However, some generalizations are useful, particularly with regard to the context of military use. In addition to natural parameters when considering military use of land, it is critical to include anthropogenic landuse patterns, particularly in consideration of training and testing lands used during peacetime and during war.

4.1 Physical Factors

The desert environment encompasses, at varying scales, both unique and common physical attributes when compared to other operational environment. Four comprehensive landform types were delineated that provide the best means of differentiating among the major deserts in terms of the Army testing and training mission requirements. Bedrock highlands, pediments and alluvial fans, desert flats and plains, and sand accumulations, are the four dominant desert landforms. Most deserts include some spatial extent of each of these landforms, but the relative percent of each varies greatly.

4.2 Relief and Landforms

The areal extent of mountainous and relatively flat terrain, expressed as a percentage of regional surface area, provides an important characterization of desert relief. Some desert areas are dominated by low relief features such as those in southern Iraq, northern Kuwait and eastern Saudi Arabia. Other locations such as the southern Sinai Peninsula, a large portion of the Atacama Desert in South America, and the Great Basin and Mojave Desert in North America, are dominated by more extreme relief. The mean elevation of a particular desert location has a strong influence on temperature and humidity and, to a lesser extent, on insolation.

4.3 Surface Mantles

It is critical to include natural surface cover in any discussion of desert environments for two reasons. First, desert surface mantles are usually clearly discernable and can therefore be used to delineate between arid regions. Second, deserts are prone to naturally occurring dusty conditions that are a function, in part, of surface mantles. This characteristic is directly related to climate, but the production of anthropogenic dust must be considered in a military context where vehicular movement in deserts is considered. The effect of various surface mantles is closely related to anthropogenic dust generation. Military wheeled and tracked vehicles greatly disturb the landscape and the effects of surface cover on military maneuver, as well as the effects of military maneuver on the land surface, are significant.

For our purposes, there exist four main parameters of desert mantles that can be used to differentiate or identify key, unique desert environmental variables. They are: sandy surfaces (e.g. dunes and sand sheets), the presence of stone mantled surfaces (e.g. desert pavements), rocky surfaces (e.g. bedrock highlands), and dust producing surfaces (e.g. playas). Each of these parameters provides information that enhances differentiating among the major deserts in terms of the Army testing and training mission requirements and that provides important environmental data for testing.

4.4 Climate and Dust

A key climatic factor of desert environments is the potential to produce dust. Natural dust can have a tremendous effect on military operations as was clearly demonstrated during Operation Iraqi Freedom in March 2003 when movement was nearly stopped during the 25-26th as a *Shamal* enveloped the region. Major dust storms are not caused by anthropogenic activity and surface mantles, but these factors may contribute to conditions that exacerbate the circumstances. Overall, common climatic conditions associated with warm and hot deserts provide the necessary circumstances for the generation of dust storms

As with other climates, desert winds can be local or regional. During the hotter parts of the year, strong diurnal cycles are often found, ranging from nearly calm overnight and in early morning to significant during the heat of mid-afternoon when they can be turbulent and gusty. Sustained winds generally greater than 8 m/s are able to produce dust and sand storms, such as are common in the Middle East (the *Shamal* in Iraq, for example). Winds of this strength often occur in the Arabian, Iranian, Sahara, Gobi, and Takla Makan deserts. Extended periods of winds of high velocity are far less common in the deserts of the United States.

4.5 Biological Considerations

The primary desert-related biological consideration that has implications for desert testing, training, and warfare is the density and structure of vegetation. Vegetation plays a critical role in providing concealment resources for soldiers and equipment in the field. In addition, the occurrence of vegetation in the landscape creates visual heterogeneity. The nature of the visual heterogeneity determines, in large part, the need for and the nature of effective camouflage. The primary biological distinction of all deserts is that they are generally sparsely vegetated, although relatively small areas of considerable vegetative cover may occur where runoff accumulates or ground water approaches the soil surface.

An effective classification of desert vegetation for military purposes should include the density of vegetative cover, the kind of vegetation, and the height of vegetation. Because the density of vegetation in deserts is inherently low, the ability to categorize desert vegetation by density is difficult. Description of the kind of vegetation should be limited to the perennial plant component because the presence of annual plants is limited to infrequent periods of adequate moisture. As a general rule, desert vegetation can be lumped into communities dominated by grasses versus woody plants. Desert grasses seldom exceed 1 m. Woody plants are likewise generally of low stature but may exceed 1 m. The significant presence of vegetation taller than 1 m has the potential to affect the desert viewshed by increasing surface complexity and reducing line of sight.

Given the considerations discussed above, a vegetation-based classification of deserts for military purposes has been devised. The approach relates the Meigs' Aridity Classification and Küchler's vegetation classification system (Küchler 1964) to a coarser descriptive category based upon the presence or absence of woody vegetation and upon plant height classes important to military considerations. In essence, the desert shrubform vegetation types of Küchler (1964 in Hudson and Aspenshade, 1995) (Bsp, Bzi, Dsi, Dsp, Dzp) are lumped into predominantly woody plants (W). Size classes further refine this particular group into those greater than or less than a meter (W<1 & W>1).

4.6 Land Use Planning Considerations

The model being developed of a hot/warm desert for military applications thus far consists of a summary and discussion of the climate, physical, biological variables. However, in describing the interactions between military training and testing and the desert environment, the model must also consider the required footprint and associated land use impacts that such operations have on the desert landscape. This is particularly important because the desert is a fragile ecosystem that can be severely degraded by military activities. Endangered and threatened species and critical habitats are common in deserts within the United States. Damaged plants and soils take long periods to recover, if they are able to recover at all. Any disturbance to the desert surface structure, such as desert pavements, can increase surface fluvial erosion and dust emission, reduce available soil, and reduce the overall carrying capacity of the ecosystem.

In a general sense, consideration of four land use factors (Area, Surrounding Land Use, Threatened & Endangered Species and Cultural Resources, and Sustainability) is necessary to ensure environmental sustainability and concomitantly, the sustainability of military mission activities in these locations.

4.6.1 Area

By their very nature, military operations in desert environments typically occur over large distances, with limited infrastructure to support troop and logistical movements. Many deserts occupy large terrestrial areas with sparse human settlements and relatively isolated urbanized centers. Recent military actions in the Southwest Asia Theater of Operations (*e.g.,* Kuwait, Saudi Arabia, Iraq) are indicative of these characteristics. Desert warfighting doctrine requires large areas for unit maneuvers. Weapons system targeting and firing require long engagement distances.

Selected land areas must be adequate for the type of training or testing to be conducted. For example, existing test firing ranges require 30-50 kilometers direct line of site for some tests. Some of the Army's largest installations are located in desert environments because of the sparse populations and the general undesirability of the land for human habitation.

4.6.2 Surrounding Land Use

In addition to adequate land and air space for actual operations and testing, adequate land and air buffer zones surrounding the operational area must be considered for both existing and future scenarios. This is largely a human safety and nuisance mitigation issue, since the potential for overshooting munitions exists. Additionally, encroachment by the surrounding populace may occur in various forms and limit the spatial or temporal extents available to conduct military activities. In addition to munitions safety concerns, there are trans-boundary noise, radio-frequency or light interferences from military activities that may occur and impact surrounding humans and wildlife. Conversely, similar interferences initiated from adjoining lands may adversely limit or impact ongoing training and tests. Therefore, an assessment of existing and future adjacent land uses is critical.

Site access is important, both from an operational and security perspective. The relative remoteness of desert sites aids in operational security and safety from the general public point of view. However, operations personnel must be able to access the site using conventional transportation means and be able to live and work on site as required to support on-going work. Given the intensity of ambient air temperatures and sunlight in the desert, protective shelters and buildings, to include air-conditioned structures, are likely to be necessary. Additionally, access to secure water sources and electricity (via conventional or solar-powered means) is essential.

4.6.3 Threatened & Endangered Species and Cultural Resources

From an ecological perspective, it is important to consider both the direct impacts of military activities on the landscape, as well as their upslope-upwind-upstream and downslope-downwind-downstream effects on adjacent lands and populations. This is particularly important when considering the impact of military activities on humans, as well as threatened and endangered species, and cultural resources. Many installations located in desert environments contain significant resources and species which must be protected in accordance with the National Endangered Species Act and a host of federal environmental statutes and guidelines. All military installations in the U.S. must develop integrated plans for natural and cultural resources management, including the management of threatened and endangered species and their associated habitats. Because military installations are well protected and relatively undeveloped, they often become "islands of biodiversity" with significantly higher populations of threatened and endangered species than surrounding lands. Similarly, many cultural artifacts, both historical and pre-historical, exist on military lands and must be protected from the effects of military training and testing. The overall result of these factors is a reduction in the actual useable training and testing lands from the total acreage that may be available.

4.6.4 Sustainability

The environmental impacts of military operations, and similar land use activities, in desert environments has been well-documented (El-Baz, 1994; Webb and Wilshire, 1983). Failure to ensure sustainable landscapes can cause unnecessary degradation of land and resources and adversely impact operations.

The sustainability of military lands can be assessed using the concept of carrying capacity. Carrying capacity is a complex, integrated concept that is a function of two interrelated factors: (i) the inherent site characteristics (*e.g.,* soil, slope, aspect, climate) and biological regime (*e.g.,* flora, fauna, vegetation community, structure and function) of the natural environment, and (ii) its associated land uses. Although carrying capacity is a theoretical concept, it can be quantified, with some degree of certainty, by scientific observation, experimentation, and measurement. Similarly, land use, or load – in this case, military operations and testing, can be quantified by type, intensity and frequency, based upon military doctrine and historical records.

For military activities, carrying capacity can be defined as the amount (frequency and intensity) of military operations and testing (to include tactical unit maneuvers, live weapons firing, etc.) which a given landscape can accommodate over time in a sustainable manner. Land use (*e.g.*, military operations) at or below the carrying capacity allows the landscape to recover naturally and restabilize from disturbance over time. When the amount of use (load or military training) placed on the natural system exceeds the carrying capacity, a critical threshold is reached. Subsequently, without adequate time and effort to allow natural and human-induced recovery, accelerated degradation and permanent ecosystem change may occur.

5. Desert Environmental Characterization Model for Operations, Training, and Testing

The world-scale model of hot and warm desert regions in the context of military planning and operations is summarized in Table 1. This model refines the use of complex parameters described in

Section 4. Added to the natural environmental parameters are those key land use factors that determine the usability of an area for sustained training or testing. It addresses physical, biological and climatic factors to delineate desert regions.

Relief and landform are the summary parameters that best depict and characterize the physical challenges to operations and equipment posed by the harshest desert environments. The ideal site for testing of Army equipment would be an area that offers a full range of the physical conditions seen in Table 1.

The range of temperature and rainfall seen in deserts is greater than is generally perceived because these variations are masked by the intense evaporation rates produced by high insolation rates in dry air. For the purpose of this study, the focus is on the hottest and driest regions because for testing and training uses, they represent the worst case conditions for successfully conditioning military operations. In selecting testing and training sites, the worst conditions from a human and equipment standpoint are the best locations.

Biological setting is significant, but can be considered less important than climate or physical setting in describing desert environments. Biological setting does have its most significance in military operations and training, as opposed to military equipment testing, particularly for dismounted military maneuvers. Land use considerations are added to the natural environmental parameters as an initial step to address the practical considerations that must be made in evaluating sites for military testing and training, a major goal for this work. As the Army develops its combat systems and redefines the basic Army unit structure, these landuse factors become critically important. Even before the final organization is set, the basic Army unit with its new equipment is going to be expected to maneuver more rapidly over larger spaces, engage targets at distances that we cannot imagine today, and remotely characterize large expanses of the battlefield at high resolution. These factors translate into requirements for the Army for larger areas of natural terrain to test and train on in a sustainable yet realistic manner. These are the attributes which must be reflected in the land use component of the desert model.

From this it is obvious that the premise which led to this study, ‘Not All Deserts are Alike’ is clearly true. Even among the world’s hot deserts—temperatures, rainfalls, dust storms and surface conditions vary greatly. Even further, there is great variety in each of these parameters within the major deserts of the world. The data in Table 2 then define the natural environmental conditions that must be provided by the Army’s testing and training lands. This is the only way to assure that our equipment is fully tested across the range of desert conditions that could (and will) be encountered, and that our troops are properly trained to accomplish their mission under the harshest conditions that these deserts can present.

Table 1. *Geographic parameters for world desert model*

Parameter	Description
Relief, landform, and surface mantle	
• Bedrock highlands (rocky surface mantle)	Steep upland terrain and exposed rock
• Alluvial fans and pediments	Moderate slope, alluvium adjacent to bedrock source areas. Strongly dissected by deep stream beds
	• Pediments/Alluvial Fans with High Degree (>50% Surface Area) of Stone Mantles
	• Pediments/Alluvial Fans with Medium Degree (25-50% Surface Area) of Stone Mantles
	• Pediments/Alluvial Fans with Low Degree (< 25% Surface Area) of Stone Mantles
• Desert flats, plains,	Minimal slope, alluvium distant from bedrock source areas.
• Playas	Internal (closed) drainage basins
• Sand accumulations	Dunes
Climate	
• Temperature	Warm is > 20^{o} C average annual daily high temperature ; Hot is > 25^{o} C average annual daily high temperature. OR Daily average temperature in the warmest month of > 25^{o} and 30^{o} C, respectively
• Rainfall	Extremely dry < 100 mm Dry < 200mm
• Wind	Winds capable of suspending dust common
Biological	
• Vegetation largely absent	
• Sparse vegetation	• Vegetation mostly > 1 m
	• Vegetation mostly <1 m
Landuse	
• Area	Total area of installation
• Surrounding land use	Ownership and use of lands adjacent to installation
• Endangered and threatened species	Presence or absence
• Sustainability	Capability to continue current missions over time

Table 2. *Global Scale Desert Characterization Model of the World's Warmest Deserts*

Desert	Temperature[1] (°F)	Precipitation, inches/year	Dust Storms[2] frequency/intensity	Surface Terrain[3]	Vegetation[4]
Arabian	105, 123, 38	4	High	4% AF 26% SD, 27% P, and 47% BR	W>1
Australian	101, 123, 30	5 – 12	High	14% AF 31% SD, 42% P, and 13% BR	G; b
Chihuahuan	104, 120, 27	Up to 12	Low	32% AF 1% SD, 22% P, and 38% BR	W>1
Gobi	90, 115, -27	1 – 8	High	28% AF 10% SD, 34% P, and 28% BR	G; b
Iranian	108, 127, 24	4	High	26% AF 19% SD, 37% P, and 18% BR	G: arid grassland
Kalahari	94, 111, 34	Up to 12	Moderate		W>1
Kara Kum	102, 122, 23	3 – 8	High		
Mojave			Very low	32% AF 1% SD, 22% P, and 38% BR	W>1: woody shrub > 1m
Saharan	110, 136, 37	0 – 0.3	High	1% AF 28% SD, 23% P, and 43% BR	W>1; b
Somali	100, 122, 35	6	High		W>1
Sonoran		2.2	Low	32% AF 1% SD, 22% P, and 38% BR	W>1
Thar	106, 126, 46	6 – 9	Moderate		W<1, W>1
NTC			Very low	12% AF 0% SD, 6% P, and 81% BR	
YPG	106, 123, 42	2 – 4	Very low	12% AF 0% SD, 21%P, and 66% BR	

Notes:
1-- Temperatures in degree Fahrenheit, are reported in order, 1st = Summer monthly daily high, 2nd = extreme daily high, 3rd = Winter monthly daily minimum, and 4th annual average temperature.
2-- Based on summaries of Table III-7 and Figure III-4
3 – Summarized from data in this report into broad classification by percent, in order Alluvial fans and pediments (AF), sand dune (SD), Desert flats and plains (P), and Bedrock highlands(BR)

SOURCES: "Desert Testing of Military Materiel", Draft TOP 1-1-008, 27 July 1998, YPG, and data referenced in this report.

6. US ARMY YUMA PROVING GROUND

Yuma Proving Ground (YPG) was officially established as an independent proving ground in 1962 and has evolved into the Army's largest general purpose proving ground with artillery, armor, automotive, and aviation/air delivery being the major types of material assigned for testing. In 1971, the Department of Defense (DOD) designated the installation as a DOD major range and test facility, one of 21 such facilities known collectively as the Major Range and Test Facility Base (MRTFB).

YPG totals 838,173 acres which is comprised of: firing ranges (503,251 acres); mine test ranges (10,467 acres); demolition ranges (4,558 acres); combat systems ranges (68,338 acres); air delivery ranges (19,710 acres); mobility test areas (33,733 acres); impact areas (3,668 acres); drop zones (1,683 acres); training ranges (1,299 acres); cantonment areas (10,835 acres); areas controlled by others under pre-existing rights and not available for installation developmental uses (2,156 acres); and areas available for future expansion (178,476 acres). See Figure 7 for details of the proving ground land use.

YPG is a US Army designated national laboratory whose mission includes the test and evaluation of all types of military and 'dual use' commercial off the shelf (COTS) systems and equipment including testing in extreme natural environments. Such environments include desert/hot weather, humid tropic and extreme cold. The proving ground is quite literally a vast outdoor laboratory, which must consistently afford the Research, Development, Test and Evaluation (RDT&E) world laboratory repeatability conditions. All of the facilities available for general purpose testing are also available for natural environmental testing.

The YPG lies within the Sonora Desert of the southwestern U.S. The installation is configured as a rectangular U-shaped polygon with a western finger extending along the eastern bank of the Colorado River floodplain (Figure 7). The physiography within the north and west portion of this finger is dominated by complex metamorphic and granitic lithologies. The remainder of the installation is dominated by alluvial fill with a high degree of stone mantled surfaces, particularly desert pavement exhibiting dark rock coatings, or varnish. Elevations range from approximately 890 m in the northern highlands to elevations as low as 50 m in the lowest lying regions.

YPG is described employing the desert characterization model in Table 2. Initial physical analysis of the region indicates that common desert physiographic features include bedrock highlands, alluvial fans and pediments, desert flats and plains, while sand accumulations and playas are the desert landscapes notably absent at YPG. The spatial extent of bedrock highlands and the biological setting are characterized in Figures 8 and 9.

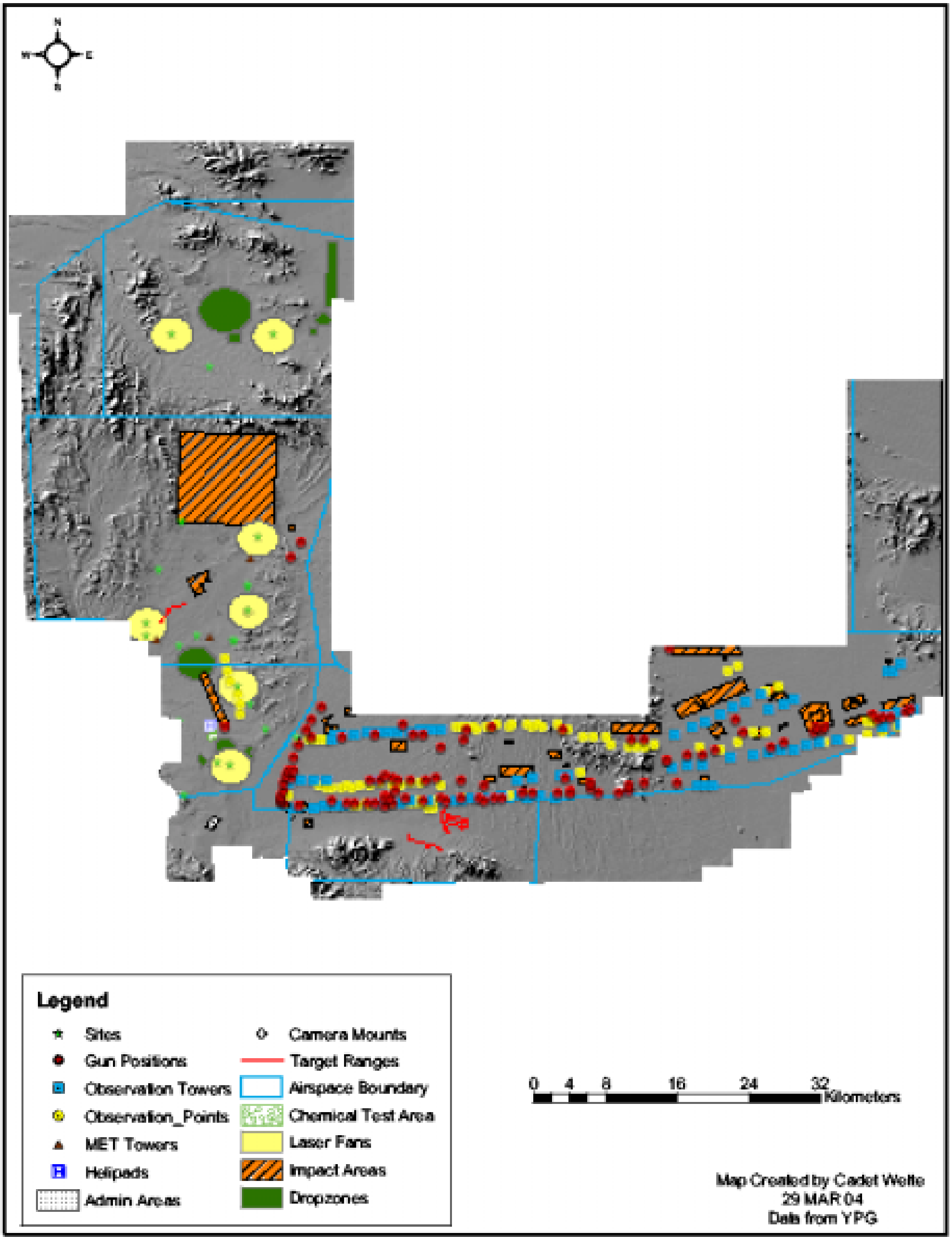

Figure 7. *YPG Land Use*

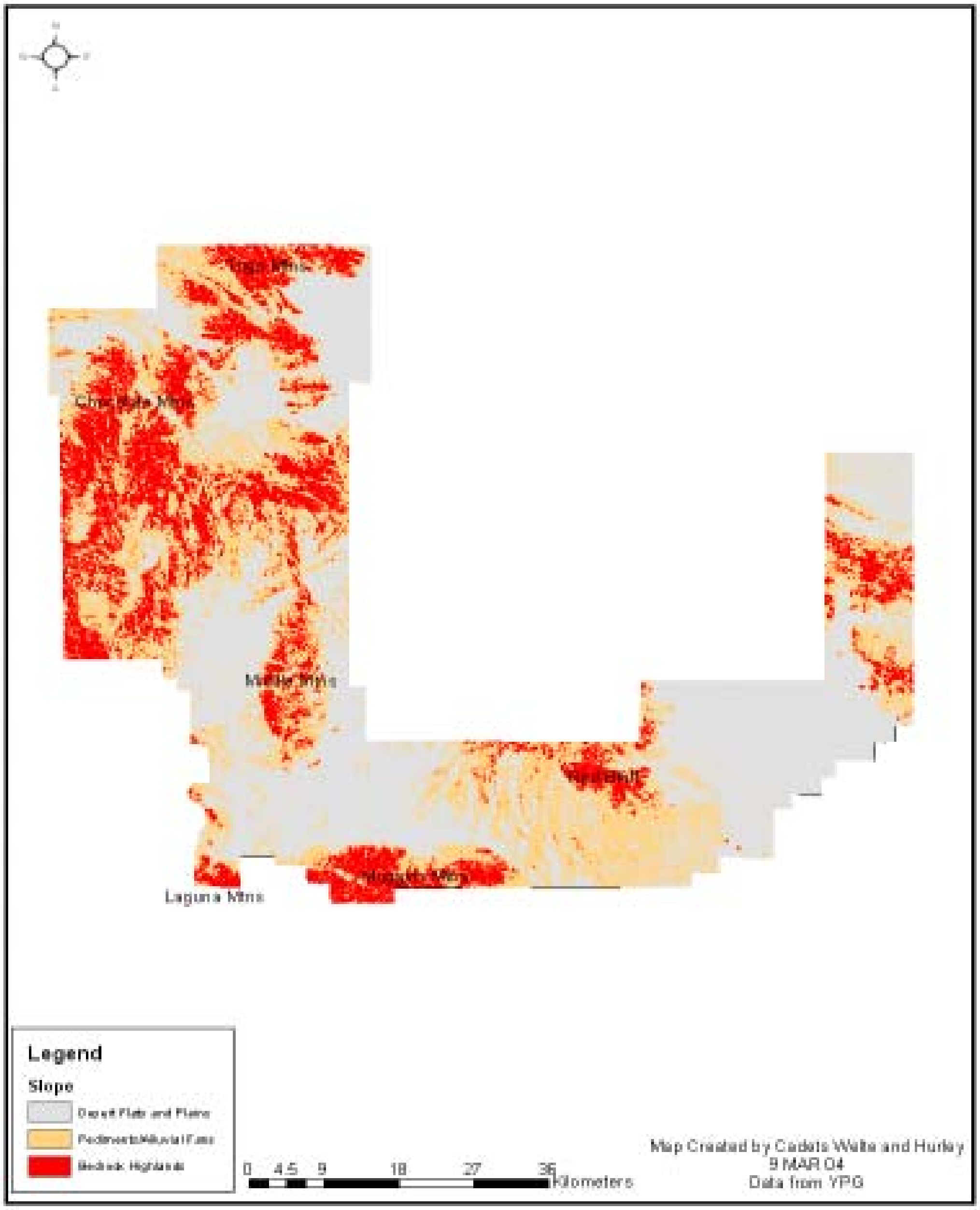

Figure 8. *YPG Bedrock highlands are shown here in red, pediments and alluvial fans in Yellow, and desert flats and plains in grey.*

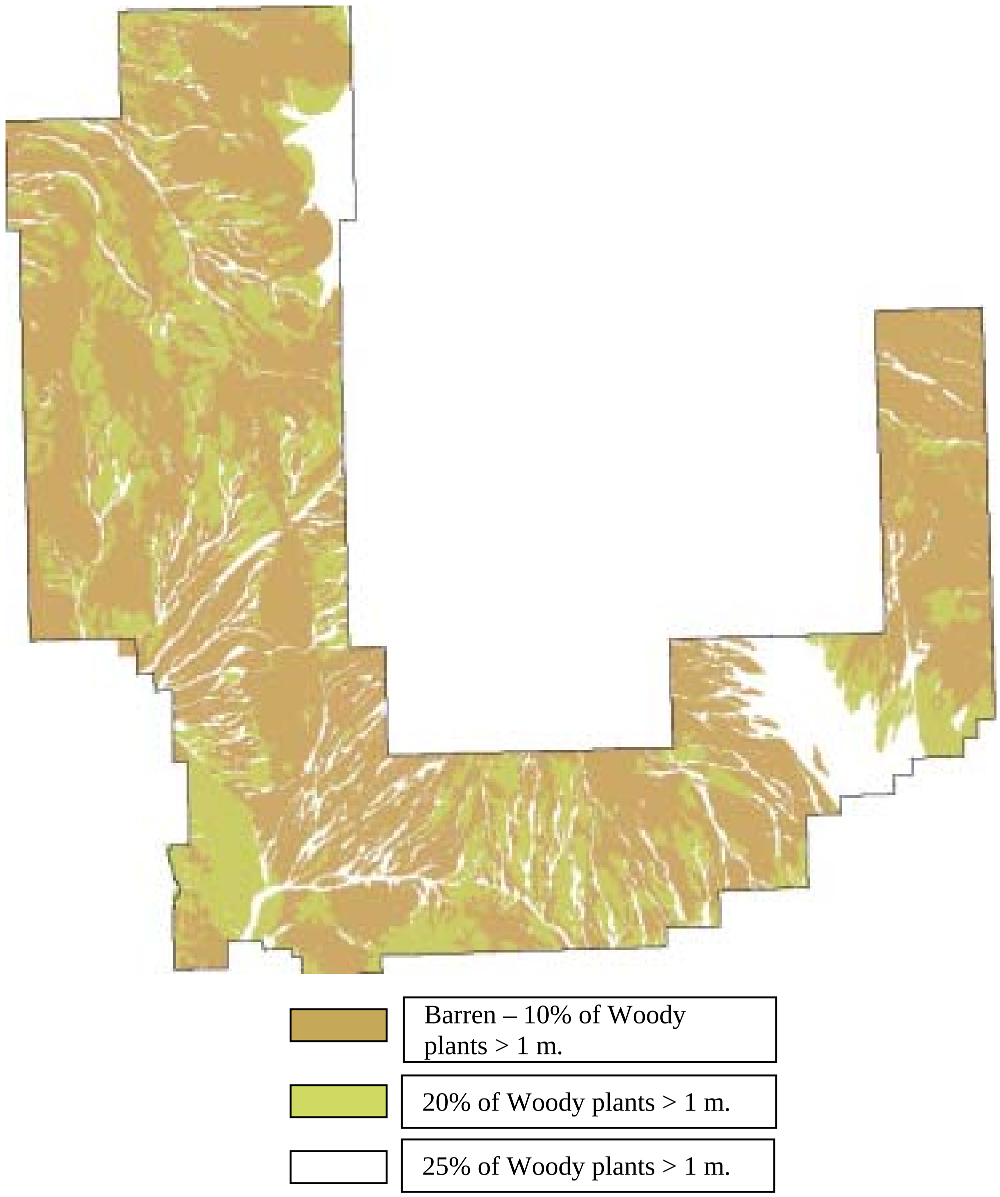

Figure 9. *Coarse description of YPG vegetative types relevant to military mission (adapted from YPG Soil Survey (Cochran, 1992) range sites and YPG LCTA Database)*

Rainfall at YPG is a mere 15 cm in the highlands and about 7 cm per year in lower elevations, averaging 9.7 cm at Headquarters. Figure 11 shows the areal distribution of annual rainfall, but is not absolute for specific areas on YPG. Along with Death Valley at 4-6 cm/yr (just north of the NTC on Figure 11) these are the driest climates in North America and the closest match to the hyperarid climates (0-5 cm) found elsewhere in the world. YPG does receive rain in both winter and summer like the southern coast of the Arabian Penninsula, the region around the Atlas Mountains in NW Africa, and southern Iraq. Winds at YPG average 3.6-4.6 m/s knots with gusts about 8.7 knots. Windstorms that can generate significant dust that last over several days such as those that accompany the Shamal winds of the Gulf or the Harmattan of West Africa are not known in this region.

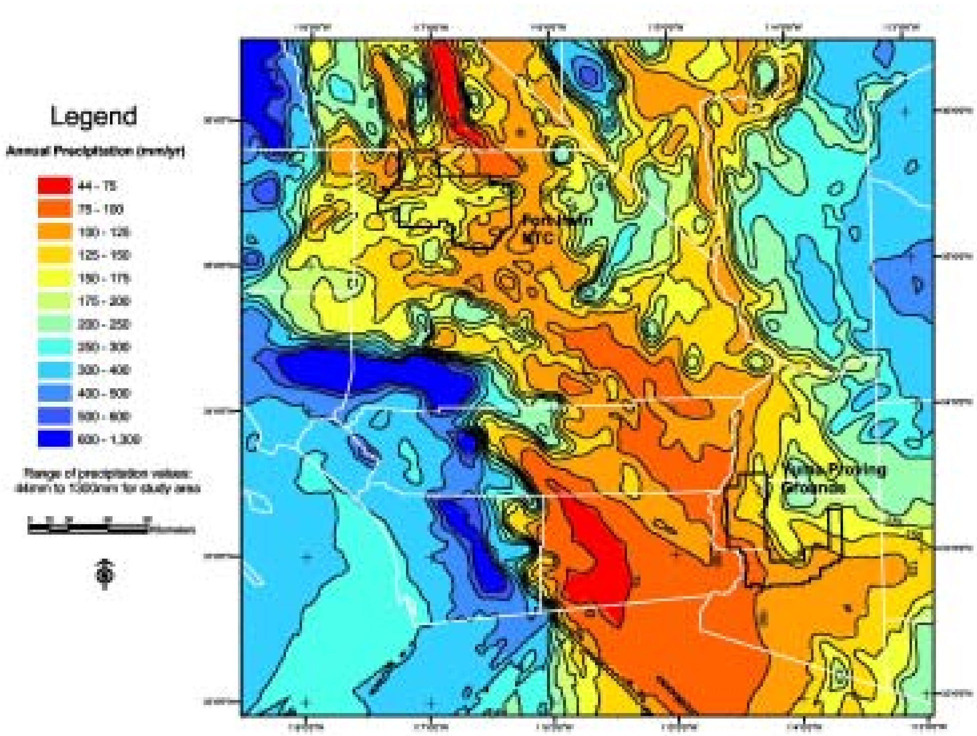

Figure 10. *Annual Rainfall Data for Western United States*

6.1 Application of Desert Model to YPG

YPG classifies as a hyperarid desert by all established geographic models. It has a highly varied physiography, which consists of approximately 66% highland areas with rough, angular bedrock. Alluvial fans and pediments dominate the low lying terrain, occupying approximately 13% of the land surface of the installation. These are all dominated by stone mantles. Most of these are considered highly mantled or moderately mantled surfaces, and few are only partially mantled. The vast majority of stone mantles can be considered desert pavements much like are present in the Negev Desert in Israel, the Atacama Desert in Peru, or the Australian Deserts. Twenty-one percent of YPG is classified in our scheme as desert flats and plains on the installation, but only two small areas of sand accumulations, both on the southern portion of the installation, exist. There are no salt accumulations or desert playas on YPG.

Climatically, YPG is similar throughout the installation with the exception of moderation to the temperature regime at the higher elevations. With the exception of Death Valley, YPG is the hottest location in the United States. It is considered a hot desert with an average monthly high temperature of over 30 ^{o}C during its warmest month. This makes it similar climatically to the hottest desert in the world including areas in the Middle East such as the Jordan River Valley, the lowlands between Baghdad and Basra in Iraq, and large areas of northeast Africa. Rainfall is limited throughout the installation with no appreciable differences spatially. Winds are relatively light throughout the year with no seasonal dust storms as encountered in other parts of the world.

The heaviest growth of vegetation at YPG occurs in wadis where influx of infrequent runoff sustains phreatophytic trees and shrubs adapted to long periods of drought. Vegetation is severely limited and sparse elsewhere on the installation with most of the vegetation well under 1 meter in height.

YPG, which covers 838,174 acres has adequate size for its current mission. The surrounding land is predominantly government land so there are minimal encroachment issues. There are no endangered species issues on the installation and the activities that take place on the installation do not apply tremendous stress to the landscape or ecosystem.

In summary provides a wide variety of desert landscape within a climate that is very hot and extremely dryA summary of the factor is presented in the desert characterization model in Table 3. These factors alone make YPG an ideal location for military desert testing and training because as will be discussed in the next chapter, YPG is a superior analog for many of the world’s hot deserts. Further, its large land area is adequate for its current mission and may provide opportunities for expanded use. The surrounding land is all government owned so there are minimal encroachment issues. There are no endangered species or cultural limitations to land use on the installation and the activities that take place on the installation do not apply tremendous stress to the landscape or ecosystem.

Table 3. *Characterization of Yuma Proving Ground*

Parameter	Description	Characterization at YPG
Relief and landform		
• Bedrock highlands	Steep upland terrain and exposed rock (> 20% slope)	48.41%
• Alluvial fans and pediments	Large sloped fans (3-20% slope). Strongly dissected by deep stream beds	30.55%
	• Pediments/Alluvial Fans with High Degree (>50% Surface Area) of Stone Mantles	~75
	• Pediments/Alluvial Fans with Medium Degree (25-50% Surface Area) of Stone Mantles	~15
	• Pediments/Alluvial Fans with Low Degree (< 25% Surface Area) of Stone Mantles	~10
• Desert flats and plains	Minimal slope (0-3%)	21.03%
• Sand accumulations	Dunes	Two small areas with dunes/lunettes exist.
Climate		
• Temperature	Warm is > 20^o C average annual daily high temperature or >30^o C in warmest month Hot is > 25^o C average annual daily high temperature or > 35^o C	YPG is considered a hot desert throughout the installation with temperatures over 30^o C in warmest month. Extremely high daily summer temperatures.
• Rainfall	Extremely dry < 100 mm Dry < 200mm	YPG receives < 100 mm of rain per annum throughout the installation, making it extremely dry
• Wind	Winds capable of suspending dust common	Occasional local storms will raise appreciable dust, but seasonal dust storms that last for more than a day are extremely rare.
Biology		
• Perennial vegetation largely absent		20%
• Sparse woody vegetation	Significant predominance of woody plants mostly > 1 m	45%
	Woody plants mostly <1 m	35%

Land use		
• Area	Total area of installation	839,403 acres, and an additional 194,046 acres of over flight space
• Surrounding land use	Ownership and use of lands adjacent to installation	Public lands surround YPG
• Endangered and threatened species	Presence or absence	There are no existing problems with endangered species protection on YPG
• Sustainability	Capability to continue current missions over time	Testing mission has a low to moderate impact on the physical environment, with the exception of drivers' training courses where high impacts are likely. Some mitigation of impacts is feasible thru ITAM and other sustainability programs.

7. US ARMY NATIONAL TRAINING CENTER, FT IRWIN

The National Training Center (Figure 13.) was established in 1979 at Fort Irwin, CA, to train up to brigade size units in a realistic natural desert environment. This training simulates rigorous combat conditions using weapons, simulators and actual live fire. It also incorporates a crafty enemy knowledgeable in the advantages of the terrain, and an expert set of trainers that critique unit actions to help improve combat effectiveness. The stress introduced in this environment is meant to develop tactically competent and tough Army units ready to win in actual combat. The proof of principle for the NTC training concept came during the Gulf War in 1991, and was reinforced with Operation Iraqi Freedom in 2003, when numerically superior enemy regular forces were quickly defeated.

The installation lies within the Basin and Range province of the southwestern U.S. The physiography is dominated by roughly parallel and alternating basins (plains) and mountain ranges (bedrock highlands) oriented NW to SE. Basins are characterized by interior drainage with common features such as playas, bajadas and deep alluvial fill. Bedrock highlands are dominated by metamorphic and volcanic lithologies. Elevations range from approximately 1800 meters in the northern highlands to 650 meters in the central maneuver corridor.

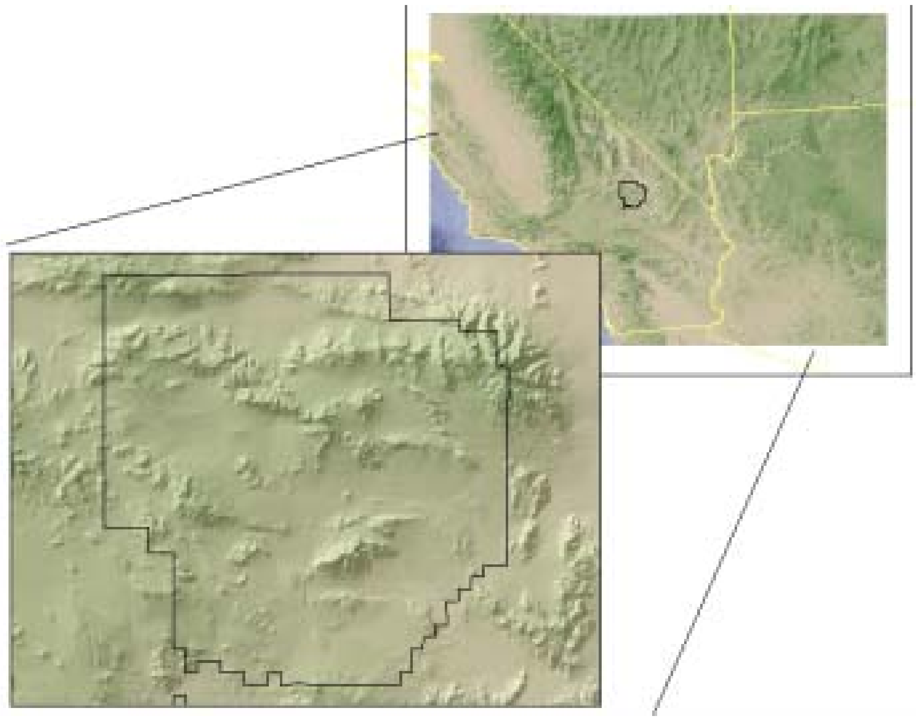

Figure 13. *Location of the National Training Center at Fort Irwin. Image taken from The Mojave Desert Ecosystem Project. http://www.mojavedata.gov/master/vector/dod/irw/owndodirw.jpg, 8 DEC 03.*

7.1 NTC Physical Description

The NTC was examined using the desert characterization model discussed previously. Initial physical analysis indicated that common physiographic features including bedrock highlands, alluvial fans and pediments, desert flats and plains, and some sand accumulations exist as the model suggests. The results of site evaluations for each of the regions of the NTC are characterized below. Because of the prevalence of stone mantled surfaces pediments and alluvial fans were subdivided as had been done for YPG. However, desert pavements are not as prevalent at NTC as they are in YPG, so the character of these stone mantles is considerably different (Fig 14).

7.2 Climate

Average daily temperatures at NTC range from 25 to 30 °C across the installation (see Figure 10.) in the warmest month. and the lowest mean monthly temperature is 7° C. The mean monthly daily high for July is mostly 35-38 ° C with small area averaging 38-39 ° C. The NTC is considerably cooler than the NTC. A comparison of temperature data from ESRI clearly shows this difference. Figure 15 (left), shows the regions of the SW US that experience an average annual daily high temperature of 25° C and higher. The region includes YPG, but not NTC. Figure 15 (right) shows the same area, but lowers the temperature range displayed to 20° C. NTC is now included.

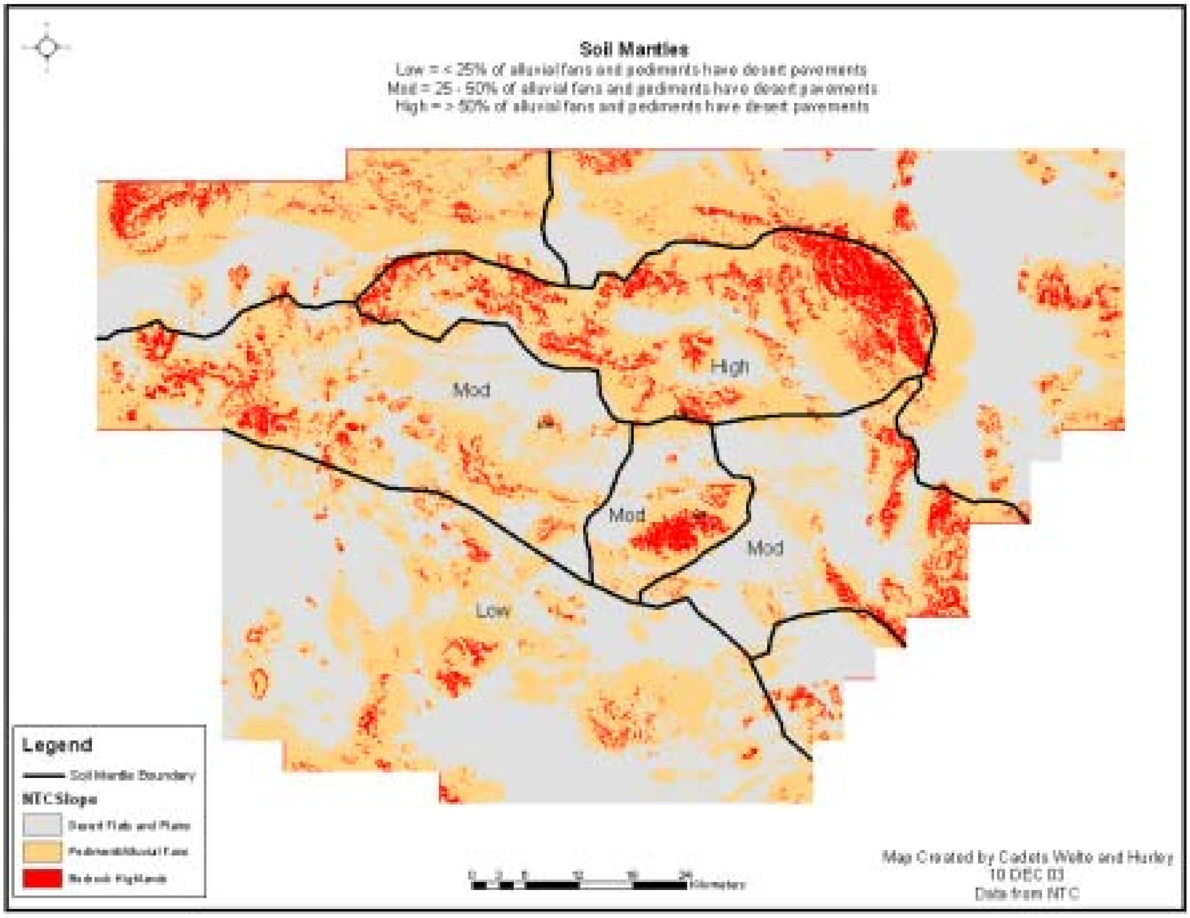

Figure 14.. *Soil Mantles at NTC. This map shows a generalization of the type of soil mantles present throughout the installation*

Temperatures at NTC vary with elevation. There are four areas of distinct lower average temperatures at NTC and they all result from altitudinal zonation. The Avawatz Mountains in the northeast portion of the installation approach 1700 m and have an annual maximum average temperature of 17-18° C (63-65° F) (minimum average annual temperature is 1-2° C [33-35° F]). The Granite Mountains in the central part of the installation peak at over 1600 m and attain an annual average maximum temperature of 19-20° C (66-67° F) (3-4° C [38-39° F] minimum), while these same mountains in the northwestern portion of the post attain a height of nearly 1650 m and also have an annual maximum average temperature of 19-20° C (66-67° F) (3-4° C [38-39° F] minimum). The last cool area on the installation is an unnamed mountain near the Goldstone Complex that attains a height of nearly 1480 m and averages temperatures of 19-20° C (66-67° F) (3-4° C [38-39° F] minimum).

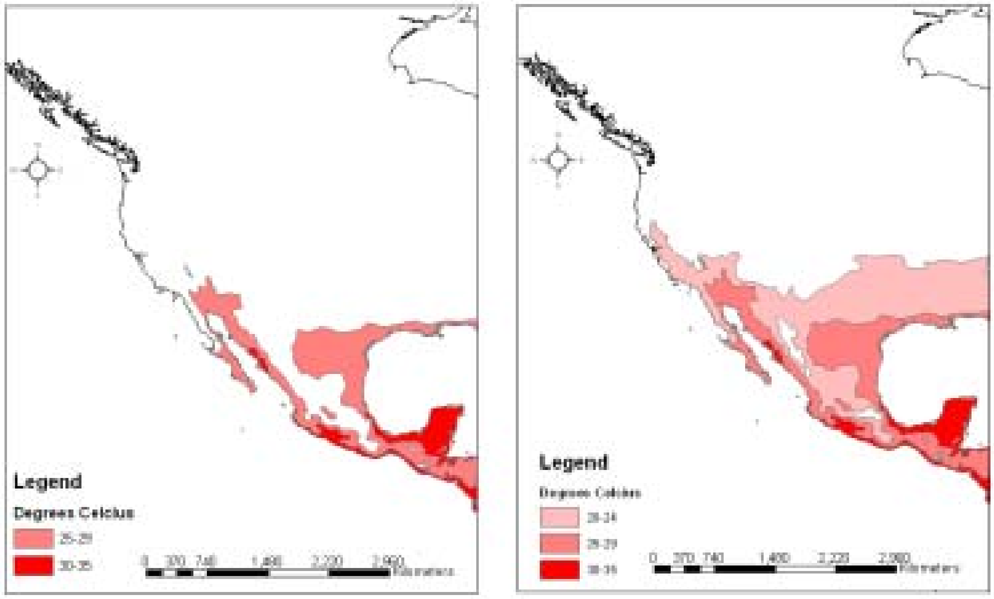

Figure 15.. *This map compares the spatial distribution of average annual high daily temperatures in the desert SW.*

Rainfall at NTC averages 9 cm (3.5 inches) annually, with the highest amount being 20-25 cm (8-10 inches) falling in the Avawatz Mountains in the northern portions of the installation (see Figure 11). This is considerably more than YPG experiences and is similar to river valleys locations in much of the Middle East, but is not a good analog to larger upland desert areas of the region. Winds at NTC average 7.7 m/s (11 knots, 13 mph) with gusts over 8.7 m/s (17 knots) and are generally from the southwest.

7.3 Biological Setting

Despite the amount of maneuver that takes place at NTC, relatively large expanses of desert vegetation remains virtually intact. Areas that have been used repeatedly by tracked and wheeled vehicles are devoid of any vegetation, but the same trails and bivouac or fighting positions tend to be used repetitively and bear the brunt of continued disturbance. As at YPG, vegetation is widely dispersed and does not provide much concealment potential (Figure 16). Again as at YPG, the dominant plant is the creosotebush, a shrub occurring in all areas of NTC except the higher elevations and barren playas. Overall, the vegetative appearance at NTC appears to be somewhat uniformly spaced and evenly low-statured. Creosotebush is generally considered to be a woody shrub larger than a meter in height, but the preponderance of plants within the southern and central corridors and similar flats and plains were well below that height. Combining this vegetative type with several others (creosotebush scrub; blackbrush scrub; creosote shadscale scrub; allscale scrub; and saltbush scrub) occurring at NTC resulted in a generalized determination that roughly 75% of NTC met the criteria for W<1 (woody plants < 1 m.).

The NTC plant communities determined to be W>1 were mixed desert scrub and creosote /

blackbrush scrub totaling approximately 10% (15% if Expansion Areas included). Although blackbrush is a dwarfshrub, its presence in the plant community infers that the dominant creosote component is healthy and mature therefore reaching its growth > 1 m in height. Unlike YPG, trees and tall shrubs in wadis are not a significant landscape component at NTC. Joshua trees (*Yucca brevifolia*), tree-like members of the agave family, occur in patches of the Western Expansion Area and upper slopes, but likely serve no military use. A stand of juniper trees (*Juniperus osteosperma*) has been discovered in NTC Avawatz Mountains (Ferris-Garcia et al, 1996), but is both too small and isolated for military activities.

The remainder of NTC is considered barren, incorporating both playas and areas of repeated disturbance, and is estimated at approximately 15% (dropping to 10% if Expansion Areas are included. NTC also documents the presence of an arid grassland community, but it appears to be too fragmented to include in this coarse scale approach.

7.4 Application of the Desert Model to NTC

The NTC lies within the high Mojave Desert and is much cooler and wetter than YPG. Its average altitude above sea level is greater than YPG. Highlands make up nearly 82% of the land. Pediments and alluvial fans make up about 12%, and desert flats and plains are present on only about 6% of the installation. NTC does boast several playas, which are not present at YPG. However, there are no sizeable sand accumulations in the form of dunes at NTC.

Temperatures at NTC should not be considered similar throughout the installation. Higher elevations are cooler, and two areas at NTC experience the warmest temperatures primarily because of their low elevations. The southeastern portion of the installation in the vicinity of Langford Well Lake is the warmest region, and is joined in this distinction by the north central area.

Rainfall distribution on the installation is varied. More rain falls in the north-central portion of the installation (largely on the Leach Lake Impact Area) than other areas. The central area corridor is the driest. Winds can be strong, but there are no large seasonal sandstorms common in this area.

Woody vegetation is relatively uniform in distribution and evenly low-statured in height. In contrast to the classification of the Mojave Desert in § III as predominantly W>1 (woody plants > 1 m.), the more appropriate grouping specific to NTC appears to be W<1. This is both a factor of the change to a finer scale analysis and because the dominant species, creosotebush, appeared to the investigators as stunted throughout the range. It is unknown if military disturbance is the primary factor causing this anomaly; it didn't appear so in the field. In other areas NTC has a wide range of desert vegetation types and can even sustain small isolated stands of more mesic species such as Juniper. Areas that are barren or devoid of perennial vegetation occur in playas and heavily disturbed areas. During periods of adequate rainfall, the playas may temporarily hold water but do not support plants because of high salt concentrations. Disturbed sites will briefly sustain annual plants, unfortunately including a preponderance of invasive species.

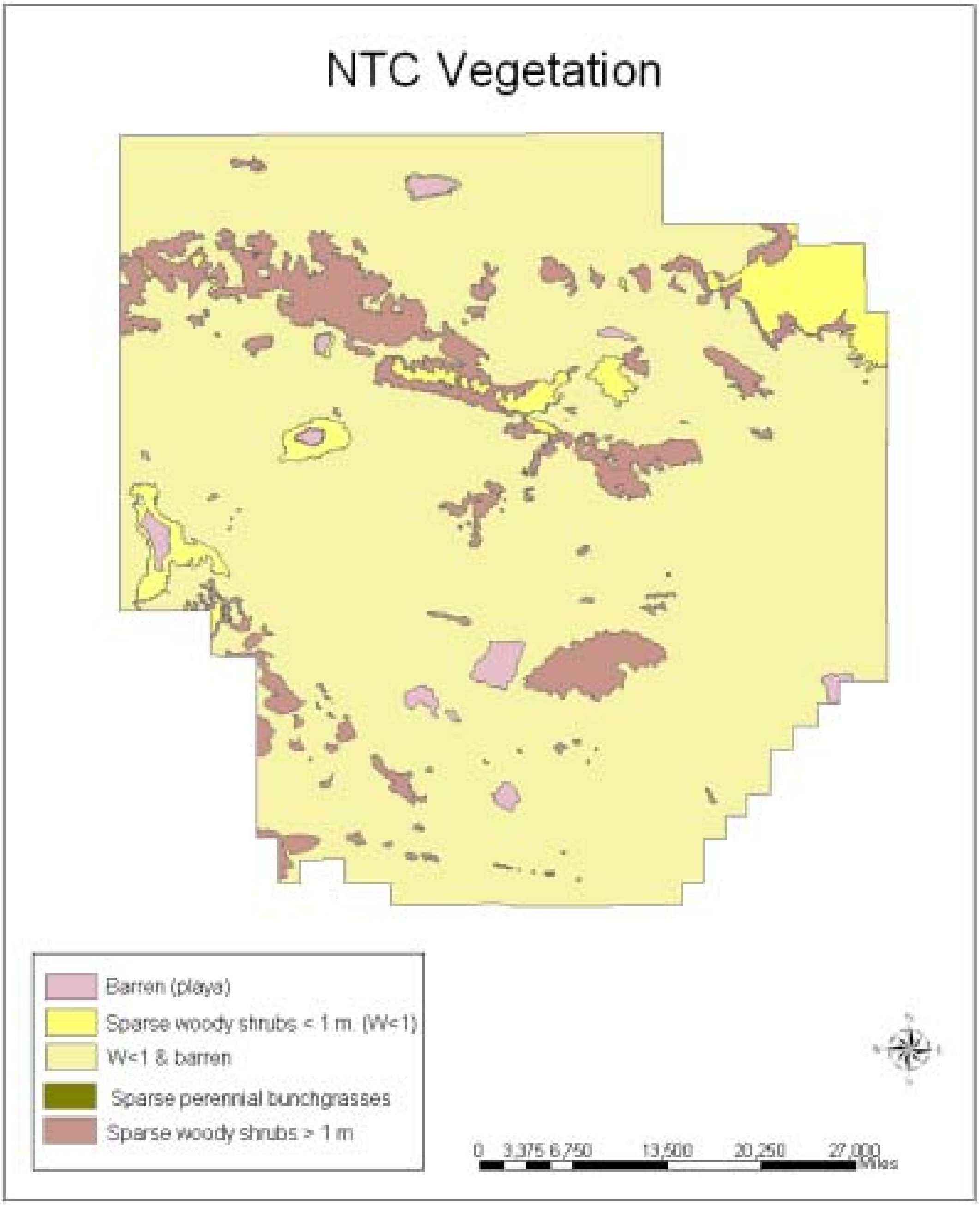

Figure 16. *Primary Vegetation Types at Ft Irwin*

8. FINDINGS AND CONCLUSIONS

8.1 The Problem of Preparing for a World Wide Mission

Operations in non-temperate environments will always be a challenge for US Armed Forces. Despite our best efforts to test equipment and train troops in harsh, unfamiliar regions, contemporary geopolitical realities and the geography of the United States dictate that the majority of U.S. forces will be stationed and trained in temperate areas. When crises arise in other environments, units with little or no recent experience in these areas often must be sent, and their equipment must function as expected despite extreme environmental conditions. The 3rd Infantry Division (ID), stationed in the humid subtropical climate of Fort Stewart, Georgia, for example, deployed and fought in Iraq in 2003. Other units, including the 7th Cavalry out of Fort Hood, Texas, also humid subtropical climate, and the 1st Marine Expeditionary Force out of Camp Pendleton, California, a Steppe climate, also fought there and stayed in the region throughout the summer. Temperatures during this period around Baghdad average 110 ^{o}F, with a 20 – 30 ^{o}F daily range (Pannell, 2002). While it is preferable to provide an acclimation and training period in similar environmental conditions to those expected in the theater of operations, this study clearly indicates that not all of the critical environmental conditions present in Iraq were available within the training posts in the United States. Our testing and training facilities must be capable of providing adequate and long term accessibility to a wide range of conditions to accomplish their functions. Yuma Proving Ground is the only location in the United States that provides extremely hot and hyperarid conditions necessary to simulate the harshest desert environments, while NTC provides excellent conditions for warm desert training. Neither can duplicate large dune areas or the harsh dust storms that are present in potential future conflict areas.

8.2 Findings on a World Scale:

Desert is a very general term describing a geographic area or region that exhibits the properties of a relatively dry climate, high evaporation rates, and sparse to no vegetation. The exact measures that define a desert such as levels of rainfall, temperature, and density of vegetation are not well established. However one defines the exact boundaries of the world's deserts, these regions are very important militarily. It was the initial hypothesis of this study that for military testing, training, and operations, all deserts are not alike and that understanding these differences are of critical importance in the world-wide mission of the United States Army. All of the evidence collected in this research strongly supports this initial hypothesis. Further, this study has found a method to meet the needs of the military to better characterize the primary differences in deserts – a geographic model of the ideal desert testing site.. This geographic characterization model recognizes that at the world level only summary analysis can be conducted, while for smaller areas more detailed analysis can be achieved. The conclusions derived from this study will follow the same principle of scale, presenting general findings for the model and world characterization analysis, followed by specific and more detailed findings and conclusions describing Ft Irwin and Yuma Proving Ground.

8.3 Conclusions

This study began with a purpose of achieving a better understanding of the militarily significant differences in the deserts of the world. This has been achieved. It was determined that not only are there great difference in the climate, physical and biotic setting of the world's main deserts, but that within each of these deserts there exists great variety. The world's hottest deserts represent the worst case condition for successful military operations, and therefore, should be the basis for selecting testing and training facilities.

A model which defines the key environmental parameters in differentiating between deserts was developed and applied to the world's deserts. This model was then used to analyze the diversity of conditions found at Yuma Proving Ground and the National Training Center at Ft Irwin. This analysis demonstrated that the model could discriminate differences in natural desert environments. For example, Figure 17, shows the differences in terrain relief between the two installations. The analysis further showed that both YPG and the NTC have great value to the Army in training and testing, but that the two installations are quite different in the natural setting they offer.

8.4 Comparison of the NTC, YPG, and the World's Deserts

Compiling the data presented in this report into the format of the desert characterization model allows comparisons of the world's deserts with these two installations, as seen in Table 4.

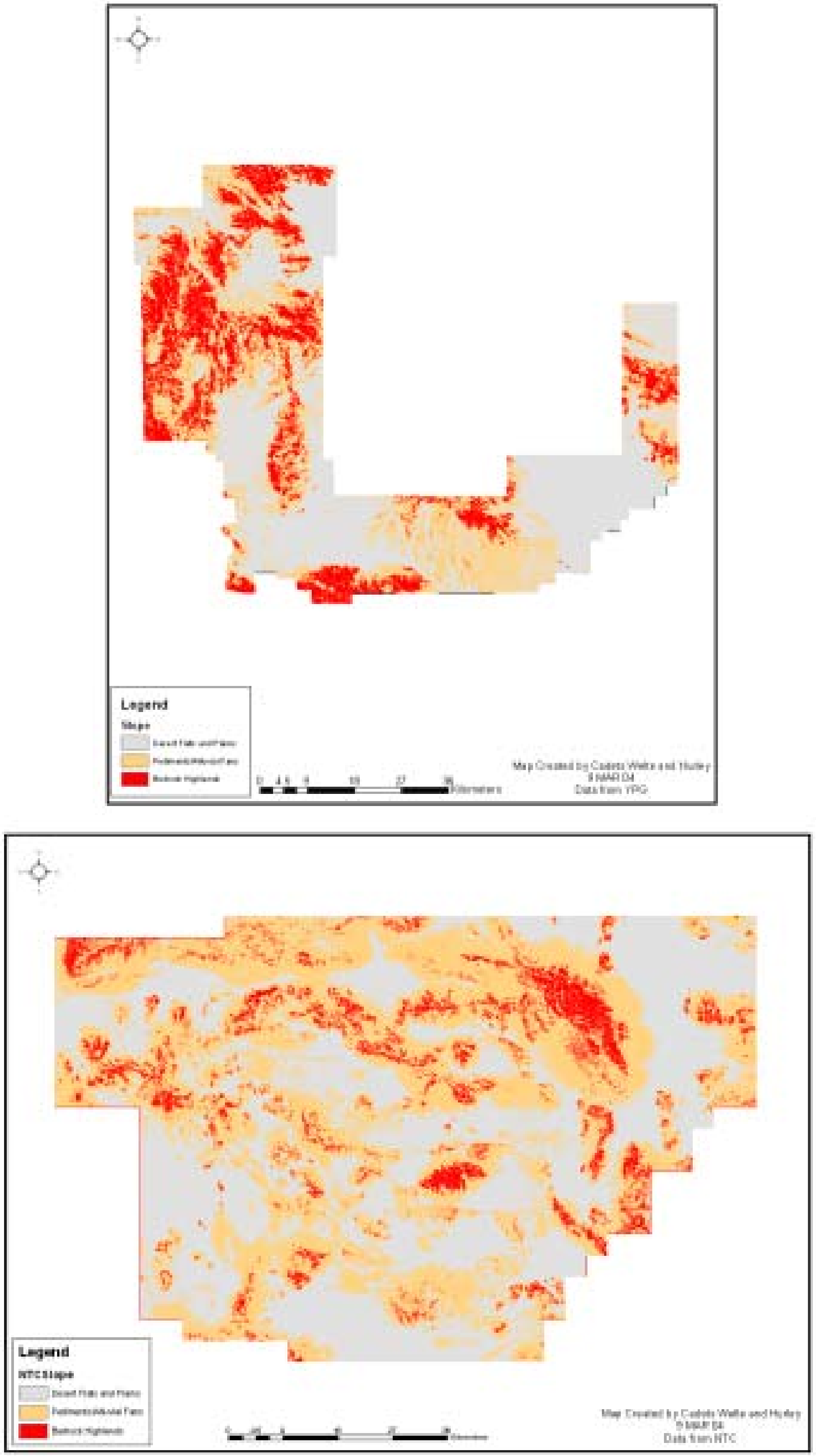

Figure 17. Differences in relief between YPG and NTC are clearly shown in this figure.

Table 4. *Characterization and Comparison of YPG and NTC with the World's Deserts*

Parameter	Description	Characterization at NTC	Characterization at YPG	World Deserts
Relief and landform				
Bedrock highlands	Steep upland terrain and exposed rock (> 20% slope)	56.90%	48.41%	Arabian (47%), Sahara (43%), Australia (16%)
Alluvial fans and pediments	Large sloped fans (3-20% slope). Strongly dissected by deep stream beds	36.76%	30.55%	Sahara (10%)
	Pediments/Alluvial Fans with High Degree (>50% Surface Area) of Stone Mantles	25%	75	Gobi
	Pediments/Alluvial Fans with Medium Degree (25-50% Surface Area) of Stone Mantles	15%	15	Gobi
	Pediments/Alluvial Fans with Low Degree (< 25% Surface Area) of Stone Mantles	60%	10	US Southwest
Desert flats and plains	Minimal slope (<10%)	6.34%	21.03%	Sahara (20%), Australia (50%
Sand accumulations	Dunes	Dunes are not well represented on NTC, but two areas of sand sheets exist in the southern and southeastern portion of the southern corridor where extensive maneuver has altered natural vegetation and soil surfaces.	Two small areas with dunes/lunettes exist.	Arabian (26% sandy) Sahara (28-30% sandy) Australian (38% sandy) Kara Kum Kyzul Kum (mostly sandy)
Climate				
Temperature	Warm is > 20o C average annual daily high temperature Hot is > 30o C average annual daily high temperature		YPG is considered a hot desert throughout the installation.	Hot: Arabian, Sahara, Australian Warm:
Rainfall	Extremely dry < 100 mm Dry < 200mm		YPG receives < 100 mm of rain per annum throughout the installation	
Wind	Winds capable of suspending dust common	Occasional local storms will raise appreciable dust, but seasonal dust storms that last for more than a day are extremely rare.	Occasional local storms will raise appreciable dust, but seasonal dust storms that last for more than a day are extremely rare.	

Parameter	Description	Characterization at NTC	Characterization at YPG	World Deserts
Biology				
Vegetation largely absent		15%	20%	Sahara, Arabian, Namib, Australian
Sparse vegetation	Vegetation mostly > 1 m	10%	45%	
	Vegetation mostly <1 m	75%	35%	
Land Use				
Area	Total area of installation	747,448 acres, including Goldstone space communications facility and protected terrain for habitat of endangered species, and the Western and Eastern Expansion Areas (112,000 acres)	838,173 acres, and an additional 400,00 acres of over flight space	
Surrounding land use	Ownership and use of lands adjacent to installation	Mostly public lands surround NTC	Public lands surround YPG	
Endangered and threatened species	Presence or absence	Desert Tortoise habitat partially located in the southern maneuver corridor: Lane Mountain Milk Vetch habitat located in the Superior Valley (eastern expansion area).	No endangered species exist on YPG	
Sustainability	Capability to continue current missions over time	Maneuver training has a moderate to high impact on the physical environment. Major maneuver corridors have been significantly impacted beyond natural recovery state, and constitute “sacrifice areas”. Some mitigation of impacts is feasible thru ITAM and other sustainability programs.	Testing mission has a moderate to low impact on the physical environment, with the exception of drivers’ training courses where high impacts are likely. Some mitigation of impacts is feasible thru ITAM and other sustainability programs.	

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