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REVIEW ARTICLE

The Colour of Semnan Desert Soils in Iran

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ABSTRACT

A desert is a barren area of land where little precipitation occurs and consequently living conditions are hostile for plant and animal life. The lack of vegetation exposes the unprotected surface of the ground to the processes of denudation. Minerals, bacteria, organic matter and air. Without any one of these ingredients present in the soil it is not true soil. The colour of laterite soil depends upon where it is. In temperate climates it will be yellow, but in tropical climes it will be red. This is because the iron oxide, which is mainly responsible for the colour, oxidizes to a different form in higher temperatures. Laterite soil is rich in iron oxide and aluminum and is derived from a wide variety of rocks through leaching. It is formed in hot and wet tropical areas and is blackish brown to reddish in color. The crops grown in laterite soil are coconut tea and coffee. It is rich in iron and aluminum hydroxide. Desert soils are downright unusual! They vary tremendously in texture; many are sandy and gravelly, while others contain layers of sticky clay, or even rock-hard, white limy layers. Desert soils may be gray-colored, brown, or even brick red. In the more arid parts of the Sonoran Desert, surfaces of some soils are covered by a layer of small stones that can be as tightly interlocked as pieces of an ancient Roman mosaic, and are coated with dark, shiny rock varnish. Many of these diverse features of desert soils have taken thousands of years or more to form. Characteristics of these soils also greatly affect and are greatly affected by, desert organisms.
Keywords: Soil, Desert, Minerals, Bacteria, Organic matter and Air.

INTRODUCTION

Soil Formation

The varied geological terrains of the Sonoran Desert provide many different kinds of parent materials in which soils form. Gravelly or stony alluvial fans that spill out of mountain drainages into adjacent basins cover much of the face of the Sonoran Desert (see the chapter "The Geologic Origin of the Sonoran Desert"). The sediments transported all the way to the floors of these basins are usually much finer—sands, silts and clays. The mountains themselves possess various rock types, slopes, and exposures that offer a complex array of different soil-forming environments. The monstrous heaps of wind-blown sand in the dune fields of the Gran Desierto in northwestern Sonora and the Cactus Plain east of Parker, Arizona, provide yet another kind of soil parent material.

Soils initially form within the physical matrix of the parent material. Over time, the composition and location of substances within the developing soil change and move around, altering the soil's characteristics. Water is responsible for most of this work of alteration and transportation of materials in soils, even in deserts. Physical and chemical weathering reduces the sizes of coarse particles. Chemical reactions convert some minerals contained in the parent materials into clay minerals. Other chemical reactions paint the soil's colors. Wind-blown dust and solids dissolved or suspended in raindrops slowly add new materials to the desert's surface, and water moves some of these materials downward into the soil. Living things residing in and on a soil further influence the soil's development. All of these processes take time; desert soils that have formed in parent materials that were deposited long, long ago differ considerably from those that have formed in younger deposits (Lynn and Pearson, 2000).

The first impression we have when looking at bare earth or soil is of color. Bright colors especially, catch our eye. Geographers are familiar with Red Desert soils in California, Arizona, and Nevada (Arizona State Soil); and Gray Desert soils in Idaho, Utah, and Nevada (Nevada State Soil). We have the White Sands in New Mexico, Green Sands along the Atlantic Coast, and Redbeds in Texas and Oklahoma (Oklahoma State Soil). The Red River between Oklahoma and Texas carries red sediment downstream, particularly in times of flood. The Yellow River (Hwang Ho) in China carries yellow sediment. Surface soils in the Great Plains and Corn Belt are darkened and enriched by organic matter like the dark brown or black soils found in Illinois (Illinois State Soil).

Earth materials found in such locations as those mentioned above were used as coloring agents early in the development of most human cultures. As earth material was fashioned into utilitarian vessels, artistic colors inevitably were incorporated into them. Indigenous North American cultures used contrasting earth colors as body paints, and modern American culture uses colored earth in cosmetics and ceramics and as pigments for paints.

Munsell Color System

Red, brown, yellow, yellowish-red, grayish-brown, and pale red are all good descriptive colors of soil, but not very exact. Just as paint stores have pages of color chips, soil scientists use a book of color chips that follow the Munsell System of Color Notation (www.munsell.com). The Munsell System allows for direct comparison of soils anywhere in the world. The system has three components: hue (a specific color), value (lightness and darkness), and chroma (color intensity) that are arranged in books of color chips. Soil is held next to the chips to find a visual match and assigned the corresponding Munsell notation. For example, a brown soil may be noted as: hue value/chroma (10YR 5/3). With a soil color book with Munsell notations, a science student or teacher can visually connect soil colors with natural environments of the area, and students can learn to read and record the color, scientifically. Soil color by Munsell notation is one of many standard methods used to describe soils for soil survey. Munsell color notations can be used to define an archeological site or to make comparisons in a criminal investigation. Even carpet manufacturers use Munsell soil colors to match carpet colors to local soils so that the carpet will not show the dirt (soil) tracked into the house (Bassett, 1989).

Interpreting Soil Color

Color can be used as a clue to mineral content of a soil. Iron minerals, by far, provide the most and the greatest variety of pigments in earth and soil (see the following table).

Properties of Minerals				
Mineral	**Formula**	**Size**	**Munsell**	**Color**
goethite	FeOOH	(1-2 m m)	10YR 8/6	yellow
goethite	FeOOH	(~0.2 m m)	7.5YR 5/6	strong brown
hematite	Fe2O3	(~0.4 m m)	5R 3/6	red
hematite	Fe2O3	(~0.1 m m)	10R 4/8	red
lepidocrocite	FeOOH	(~0.5 m m)	5YR 6/8	reddish-yellow
lepidocrocite	FeOOH	(~0.1 m m)	2.5YR 4/6	red
ferrihydrite	Fe (OH)3		2.5YR 3/6	dark red
glauconite	K(SixAl4-x)(Al,Fe,Mg)O10(OH)2		5Y 5/1	dark gray
iron sulfide	FeS		10YR 2/1	black
pyrite	FeS2		10YR 2/1	black (metallic)
jarosite	K Fe3 (OH)6 (SO4)2		5Y 6/4	pale yellow
todorokite	MnO4		10YR 2/1	black
humus			10YR 2/1	black
calcite	CaCO3		10YR 8/2	white
dolomite	CaMg (CO3)2		10YR 8/2	white
gypsum	CaSO4× 2H2O		10YR 8/3	very pale brown
quartz	SiO2		10YR 6/1	light gray

Soil Composition and Color

Soil color and other properties including texture, structure, and consistence are used to distinguish and identify soil horizons (layers) and to group soils according to the soil classification system called *Soil Taxonomy*. Color development and distribution of color within a soil profile are part of weathering. As rocks containing iron or manganese weather, the elements oxidize.

Iron forms small crystals with a yellow or red color, organic matter decomposes into black humus, and manganese forms black mineral deposits. These pigments paint the soil (Michigan State Soil). Color is also affected by the environment: aerobic environments produce sweeping vistas of uniform or subtly changing color, and anaerobic (lacking oxygen), wet environments disrupt color flow with complex, often intriguing patterns and points of accent. With depth below the soil surface, colors usually become lighter, yellower, or redder (Chew and Whitford, 1992). Relatively large crystals of goethite give the ubiquitous yellow pigment of aerobic soils. Smaller goethite crystals produce shades of brown. Hematite (Greek for blood-like) adds rich red tints. Large hematite crystals give a purplish-red color to geologic sediments that, in a soil, may be inherited from the geologic parent material. In general, goethite soil colors occur more frequently in temperate climates, and hematite colors are more prevalent in hot deserts and tropical climates (Drake et al., 1993). Color - or lack of color - can also tell us something about the environment. Anaerobic environments occur when a soil has a high water table or water settles above an impermeable layer. In many soils, the water table rises in the rainy season. When standing water covers soil, any oxygen in the water is used rapidly, and then the aerobic bacteria go dormant. Anaerobic bacteria use ferric iron (Fe^{3+}) in goethite and hematite as an electron acceptor in their metabolism. In the process, iron is reduced to colorless, water-soluble ferrous iron (Fe^{2+}), which is returned to the soil. Other anaerobic bacteria use Mn^{4+} as an electron acceptor, which is reduced to colorless, soluble Mn^{2+}. The loss of pigment leaves gray colors of the underlying mineral. If water stays high for long periods, the entire zone turns gray (Gile, 1975).When the water table edges down in the dry season, oxygen reenters. Soluble iron oxidizes into characteristic orange colored mottles of lepidocrocite (same formula as goethite but different crystal structure) on cracks in the soil. If the soil aerates rapidly, bright red mottles of ferrihydrite form in pores and on cracks. Usually ferrihydrite is not stable and, in time, alters to lepidocrocite.

Along seacoasts, tide waters saturate soils twice daily, bringing soluble sulfate anions. Anaerobic bacteria use the sulfate as an electron acceptor and release sulfide (S^{2-}) which combines with ferrous iron to precipitate black iron sulfide. A little hydrochloric acid (HCl) dropped on this black pigment quickly produces a rotten egg odor of hydrogen sulfide (H_2S) gas. Soils that release H_2S gas are called sulfidic soils. With time, iron sulfide alters to pyrite (FeS_2) and imparts a metallic bluish color. If sulfidic soils are drained and aerated, they quickly become very acid (pH 2.5 to 3.5), and a distinctive pale yellow pigment of jarosite forms. This is the mark of an acid sulfate soil that is quite corrosive and grows few plants.

Galuconitic green sands form in shallow ocean water near a coast. They become part of soils that form after sea level drops. White colors of uncoated calcite, dolomite, and gypsum are common in geologic materials and soils in arid climates. A little carbonate dissolves in water, moves downward, and precipitates in soft white bodies or harder nodules. It also accumulates in root pores as lacy, dendritic (tree-branch) patterns (Gile et al., 1981).

Influence of Organic Matter on Soil Color

Soil has living organisms and dead organic matter, which decomposes into black humus. In grassland (prairie) soils the dark color permeates through the surface layers bringing with it nutrients and high fertility (Kansas State Soil).

Deeper in the soil, the organic pigment coats surfaces of soil, making them darker than the color inside. Humus color decreases with depth and iron pigments become more apparent. In forested areas, organic matter (leaves, needles, pine cones, dead animals) accumulates on top of the soil. Water-soluble carbon moves down through the soil and scavenges bits of humus and iron that accumulate below in black, humic bands over reddish iron bands. Often, a white layer, mostly quartz occurs between organic matter on the surface where pigments were removed (Wisconsin State Soil). Organic matter plays an indirect, but crucial role in the removal of iron and manganese pigments in wet soils. All bacteria, including those that reduce iron and manganese, must have a food source. Therefore, anaerobic bacteria thrive in concentrations of organic matter, particularly in dead roots. Here, concentrations of gray mottles develop.

Soil color is a study of various chemical processes acting on soil. These processes include the weathering of geologic material, the chemistry of oxidation-reduction actions upon the various minerals of soil, especially iron and manganese, and the biochemistry of the decomposition of organic matter. Other aspects of Earth science such as climate, physical geography, and geology all influence the rates and conditions under which these chemical reactions occur. Soil adds beauty to our landscapes. These colors blend with vegetation, sky, and water. For art students and others who may be interested in creating a natural look to their artwork, try to incorporate finely ground colored soils as pigments into your work (Gile and Grossman, 1968).

You can readily observe the effect of time on the degree of soil development in alluvial fans deposited at different times throughout the region. Pleistocene deposits (2.4 million to 11,000 years old) may cover the land surface in some places, especially in areas nearer the mountains, while elsewhere, geologically younger Holocene deposits (less than 11,000 years old) are present. The alluvial deposits on the southwest side of the Tortolita Mountains near Tucson provide an example. Water in Wild Burro Wash transported large volumes of gravelly to rocky alluvium out of Wild Burro Canyon and deposited these materials in alluvial fans on the broad, gently sloping piedmont (see the photograph and matching landscape diagram above). Some of these materials were deposited perhaps more than 100,000 years ago, and the surfaces of some of these ancient alluvial fans, although somewhat eroded, still persist. Beneath these old land surfaces are soils that have developed thick, red- colored clayey layers underlain by accumulations of white caliche (defined and discussed below). In contrast, soils in nearby, considerably younger Holocene deposits lack the bright red coloration and accumulations of clay and lime. Soils in both the Pleistocene and Holocene deposits started out with the same kind of parent materials: gravelly to rocky, granitic alluvium almost totally devoid of clay and lime. The great contrast in the amount of time over which the soils have developed is responsible for the differences in soil characteristics.

Soil Layers: Clay, Colors, and Caliche

Many soils of the piedmonts and basin floors of the Sonoran Desert start out as deposits of gravelly or stony alluvium which have fairly uniform characteristics throughout. With the passage of time, however, pronounced horizontal layers called soil horizons develop. You can often easily see these horizons in older, well-developed soils because they differ from each other in color.

You may also detect them by changes in texture and other characteristics. Soil horizons form in arid and semi-arid regions through the downward transport of materials by water and the accumulation of various materials at characteristic depths. The depth at which materials accumulate depends mostly on how much precip-itation is received (greater amounts of precipitation soaking into the soil transport materials to greater depths) and on the kind of material that is being transported (Gile et al., 1966).

Calcic Horizons

Many desert soils contain prominent, whitish layers called calcic horizons. These are accumulations of calcium carbonate, the same material found in chalk, concrete, and agricultural lime. In the Sonoran Desert, the tops of these horizons are typically less than twenty to forty inches (50 to 100 cm) below the soil surface. Calcic horizons may be very thin (six inches; 15 cm) in some soils and contain only small amounts of calcium carbonate. In other soils, these horizons may be very thick (greater than three feet; 1 m) and strongly cemented. These nearly impenetrable, cemented layers, or petrocalcic horizons, are commonly called caliche.

For a long time the source of the tremendous amounts of calcium carbonate contained in calcic horizons of desert soils was a mystery. An obvious suggestion was that the original parent materials provided the necessary calcium. This explanation is plausible for parent materials containing limestone and other calcium-rich rocks. However, thick calcic horizons are also found in soils that have formed in parent materials that contain little or no calcium, such as alluvium derived from many igneous rocks or non-calcareous sedimentary and metamorphic rocks. In soils developed in these parent materials, the calcium clearly comes from somewhere else. Another commonly held belief is that groundwater deposited these limy soil layers. Yet calcic horizons are found even in soils where the depth to groundwater exceeds 330 feet (100 m)— even in days before extensive groundwater pumping—and where there is clear evidence that groundwater was far from the surface even during less arid conditions of the last glacial episode more than 11,000 years ago.

In addition to dust, precipitation also contains dissolved calcium. In the Las Cruces area, two to three times the amount of calcium contained in the deposited dust is delivered to the ground surface dissolved in precipitation. Water moving downward into the soil carries dissolved calcium. Plant roots and other organisms living in the soil respire, producing carbon dioxide which, dissolved in soil water, provides the rest of the chemical building blocks needed to form calcium carbonate. Calcium carbonate precipitates out of solution once the soil begins to dry. Over thousands and thousands of years, the small annual inputs of calcium in dust and precipitation add up to very large accumulations in soil calcic horizons (Johnson, 1992).

Clay-rich Horizons

Some desert soils look like a layered cake with one or more clayey, reddish-brown horizons directly above the white calcic horizon. These clay-rich layers are called argillic horizons, formed over long period of time when clay particles suspended in water are carried downward into the soil and accumulate. Like calcic horizons, the strength of development of argillic horizons depends strongly on soil age. Desert soils formed in materials deposited during the Holocene (less than 11,000 years old) usually lack argillic horizons.

Pleistocene deposits that are tens to hundreds of thousands of years old often contain pronounced argillic horizons. Argillic horizons are typically located above calcic horizons, because minute clay particles suspended (but not dissolved) in water are not transported as deeply as is dissolved calcium carbonate (see the photograph below).

In some of the moister parts of the Sonoran Desert, such as areas around Tucson that annually receive an average of ten inches (250 mm) or more precipitation, argillic horizons of some soils may be more than one and one-half feet (H m) thick and parts may contain more than fifty percent clay. Periods of abundant rainfall can turn these clay-rich layers into sticky traps that can easily mire a vehicle. In contrast, during the dry season, these clay-rich horizons become as hard as adobe brick. When they are dry, strongly developed argillic horizons often have a pronounced prismatic or blocky structure that is a product of repeated swelling and shrinking of the clays (McAuliffe, 1994). In more arid parts of the Sonoran Desert, argillic horizons are also present in many soils, but they are not as pronounced; they are much thinner and contain less clay than those found in moister regions. Argillic horizons do not form in certain kinds of parent materials in arid and semi-arid environments. Soils that have formed in calcium carbonate-rich parent materials, such as limestone or exposed calcic horizons of ancient, truncated soils, typically lack argillic horizons. The presence of calcium carbonate apparently causes clay particles to clump together in a way that prevents them from being dispersed in water, thereby inhibiting the downward movement and accumulation of the clays into argillic horizons (McFadden et al., 1987).

Soil Colors

Desert soils come in a variety of colors. Some soils have the same pale, brownish color from top to bottom, but others may be layered with browns, reds, pinks, and whites. Argillic horizons of many older soils in the Sonoran Desert are a distinct, rusty brick red. The weathering (oxidation) and accumulation of iron-bearing minerals contained in the soil produce this color. For example, biotite and hornblende are common iron- bearing minerals in parent materials derived from many kinds of igneous and metamorphic rocks. Weathering of these minerals creates new minerals, including the rust-colored iron oxide compounds. As these compounds accumulate, they paint the soil with increasingly strong reddish hues. Very young soils lack accumulations of these iron oxides and are typically pale brown or yellowish-brown. In contrast, soils that have been developing for many tens to hundreds of thousands of years on Pleistocene deposits frequently contain soils with strongly reddened horizons (Peterson, 1981). The degree of reddening that develops within a soil depends strongly on the iron content of minerals in the parent material and on how rapidly the parent materials weather. For example, some granitic rocks with abundant biotite weather very rapidly, producing strongly reddened soils. In some parent materials, the presence of extremely iron-rich minerals such as magnetite or hematite further intensifies red soil colors. Less intense reddening develops in soils derived from parent materials that are relatively poor in iron minerals and are more resistant to weathering. Some soils never develop pronounced red coloration. In deserts, only the slightest reddening of soil horizons occurs in calcareous parent materials derived from limestone, even in old soils. The predominant colors of these soils are light brownish-grays and whites of strongly-developed calcic horizons.

Soil Surfaces: Desert Pavements

Large, flat areas devoid of vegetation and covered by a layer of tightly packed small stones are conspicuous features of extremely arid landscapes. These desert pavements are rare or absent in the moister parts of the Sonoran Desert, but become increasingly pronounced in the driest parts (see the photo below).

Some of the most extensive and well-developed areas of desert pavements occur on stony alluvial fan deposits flanking the rugged, low mountains in the extremely arid lower Colorado River Valley. Geologically young deposits (Holocene-aged, less than 11,000 years) lack the flat-surfaced pavements. Surfaces of these young deposits are typically cluttered with large stones and rocks irregularly piled in elevated bars; these low bars are separated by intervening swales. This stony jumble of bars and swales is the topographic imprint of the surface's creation by the powerful tumult of moving water laden with rocky debris. Over time, though, this imprint disappears as the vertical relief of these coarse, rocky deposits is leveled out, eventually forming the flat pavement of small stones. The best-developed pavements are those that have formed over the passage of several tens of thousands to a few hundreds of thousands of years (Vanden Dolder, 1992).

Prior to this work, it was commonly believed that most desert pavements originated through the selective erosion of fine materials from the surface by either wind or water, a process called deXation. However, such a process cannot explain the development of pavements in stony parent materials that initially lacked fine-grained materials (such as many coarse-grained alluvial fan deposits or areas of exposed bedrock, including basalt flows). Nor can it explain the presence of the fine-grained Av horizon that separates the surface pavement from underlying rocky materials. In coarse parent materials, atmospheric additions of fine materials (rather than their selective removal) and incorporation of these materials into the Av horizon below a layer of stones are responsible for creation of the pavement surface.

More rarely, however, stone pavements can also be created by a process of deflation in certain environments where the original parent material consisted of small stones and pebbles mixed with abundant fine-grained sands, such as in beach deposits that ring ancient lake beds in some parts of the region. In such cases, the selective removal of the sand by wind and/or water leaves behind a lag of pebbles that resists further deflation. Once the surface lag stabilizes the fine-grained deposit, the pebbles act as a dust trap and airborne materials accumulate to eventually form a silt- and clay-rich Av horizon beneath the pebble pavement in the same manner as that which occurs on rocky parent materials. These kinds of pavements exist in a limited number of locations in the Sonoran Desert region, but are less common by far than pavements that developed on coarse, rocky parent materials as described previously (Weide, 1985).

Rock Varnish

The formation of varnish may actually be a means by which these microbes protect themselves in the exposed, extreme environment of a rock surface in the desert. Interestingly, the manganese oxides in rock varnish very effectively block the transmission of ultraviolet radiation. Perhaps the rock-dwelling microbes manufacture their own manganese-formula sun-screen!

Rock varnish forms very slowly. Surfaces of some rocks, including many coarse-grained granitic rocks, rarely sport thick coats of varnish because they weather and erode faster than varnish can form. But if rock surfaces resist weathering, varnish coatings become increasingly thick and dark with the passage of time. Rock varnish therefore provides geologists with a valuable tool for determining relative ages of different alluvial fan deposits. Stone surfaces in older deposits are generally covered by thicker, darker coats of varnish. In some cases, the thickest, darkest coatings of varnish found on older deposits may have been accumulating for many tens of thousands to over 100,000 years.

Soils and Desert Life

Soils of the desert teem with living things. Plant life ranging from single-celled cyanobacteria to giant saguaro reside on and in the soil. Tunneling termites and burrowing mammals turn over the soil. The activity of some organisms is very ephemeral and occurs in a short span of time after rains. For many others, the soil provides protection from environmental extremes, permitting year-round activity. The survival, growth, and reproduction of living things depend considerably on soil characteristics. Conersely, the activities of organisms living on and in the soil significantly influence the characteristics of soils (West, 1990).

Soil Crusts

Different soil microenvironments support different kinds of microphytic crusts. In the Sonoran Desert, larger lichens, mosses, and liverworts are more common on slopes with northern exposures; these retain moisture for longer periods after rainfall. In some fine-grained soils on the floors of basins in the hottest, driest parts of the Sonoran Desert, the dark- colored soil surface is due to the presence of untold millions of cyanobacteria or “blue-green algae.” These dark cyanobacterial crusts lie dormant most of the time but are physiologically “awakened” when the soil surface is wetted. After a rain, these organisms typically remain active for only a day or two before the soil surface again dries.

Microphytic soil crusts significantly affect soils. Cyanobacteria create sticky materials that bind soil particles together. Threadlike structures called hyphae, produced by the symbiotic fungi of lichens, knit the soil together, making it more resistant to erosion by the intense splashes of thunderstorm raindrops. Cyanobacteria can fix atmospheric nitrogen, thereby adding nitrogen to the soil in a form that potentially can be used by larger plants.

Relation Soils and Animals

Soil conditions directly affect many kinds of desert animals..Soil texture may also affect some animals by controlling the availability of water. Two similar species of large, seed harvester ants of the Sonoran Desert (*Pogonomyrmex rugosus* and *Messor pergandei*) tend to occupy soils that differ slightly in clay content. *P. rugosus* is usually found in soils with higher clay contents than those occupied by *Messor pergandei*. The reasons for this separation are not well understood, but perhaps the influence of soil texture on the infiltration and availability of water affect the two species in different ways.

Animals can profoundly affect characteristics of desert soils. The animals that dig, wriggle, tunnel and burrow through desert soils range in size from microscopic mites and nematodes to badgers and coyotes. Their activities move soil around and cycle nutrients among the realms of “animal, vegetable, and mineral.”

The soil directly beneath perennial plant canopies is enriched with organic matter and nutrients, compared to bare areas between plants.

Beneath plant canopies, organic materials are buried by the burrowing activities of mammals, and dead plant roots provide abundant organic matter on which many small animals feed. In this case, ecological wealth generates more wealth, and these "fertile islands" foster considerably higher densities and increased activity of small animals living on and in the soil.

Two groups of very small animals, arthropods and nematodes, are abundant in desert soils, especially in the fertile islands beneath plant canopies. Comparatively speaking, some of these animals are relatively large, such as the .04 to .06 inch (1-2 mm) long springtails (order Collembola), small insects that reside in leaf litter. Myriads of others, including many kinds of mites and nematodes, are extremely small, requiring a microscope to see them.

Different species of soil mites play a variety of ecological roles. Many are scavengers that feed on decomposing plant and animal material. Others are herbivores that pierce cells of plant roots with their mouthparts to drain the contents. Some are carnivores that feed on other small arthropods, other mites, and nematodes. Soil nematodes, or microscopic roundworms, are equally varied in the ecological roles they play. Some consume bacteria and other microbes; others subsist on fungi or plants or are omnivorous; some are micropredators. In turn, nematodes are the prey of other small animals, such as predaceous mites. One team of scientists estimated that the top twelve inches (30 cm) of soil at a site in the Mohave Desert contained slightly over one million nematodes per square meter (10.7 ft2). However, this tremendous number of microscopic roundworms amounted to less than .0035 ounce (1/10 gram) dry weight. Other surveys indicate similar abundances of soil nematodes in the Sonoran Desert. The minute soil arthropods and nematodes, together with the plant foods and organic matter they consume, form complex food webs of producers, prey, and predators. The operation of this web continuously recycles mineral nutrients between living and non-living components of the desert ecosystem.

Larger animals that tunnel and burrow in the soil, including termites and many kinds of rodents, are biological bulldozers. Their excavations can significantly affect characteristics of desert soils. The excavation and turnover of soil by many seed-eating rodents, such as Merriam's kangaroo rat, creates more porous soils into which water more easily infiltrates. The increased soil permeability created by the excavations of some kinds of kangaroo rats may actually benefit creosote bush plants growing on the mound-like burrow systems. In the warm deserts of the American Southwest, termites are perhaps the greatest earth-movers. Subterranean termites transport a tremendous amount of relatively deep soil materials to the surface when they construct their mud-covered tunnels on the soil surfaces and on the cellulose-containing foods they consume. In this way, desert termites accomplish the same kind of ecological role as do earthworms in soils of moister regions. In the Chihuahuan Desert of southern New Mexico, a group of ecologists estimated that termites annually brought over 1760 pounds (800 kg) of soil materials per two and one-half acres (1 hectare) to the soil surface. Termite activity in some parts of the Sonoran Desert is probably comparable. This tremendous turnover of the soil can greatly affect the formation of soil horizons and the distribution of clay, calcium carbonate and other materials. In southern New Mexico, this turnover of soil by termites has apparently thoroughly mixed soil horizons of some older soils, obliterating distinct zones of clay accumulation in argillic horizons.

Soils and Plants

The availability of water usually poses the single greatest limitation to plant life in deserts. Although desert environments are defined by the amount of precipitation received, the amount of moisture that is available for plants to use is modified by features of the soil. Subtle changes in permeability and texture affect how much precipitation is either absorbed by the soil or lost to runoff, and how deeply water infiltrates into the soil.

The different soil horizons discussed earlier affect infiltration and depth of water storage. Relatively large quantities of water can soak into the surface of a sandy-gravelly soil that lacks horizon development. A significant fraction of rainfall may infiltrate to perhaps a meter in such a deep, permeable soil. Water stored deeply is protected from evaporation to the atmosphere.

CONCLUSION

About one third of the land surface of the world is arid or semi-arid. This includes much of the Polar Regions where little precipitation occurs and which are sometimes called "cold deserts". Deserts can be classified by the amount of precipitation that falls, by the temperature that prevails, by the causes of desertification or by their geographical location.

Deserts are formed by weathering processes as large variations in temperature between day and night put strains on the rocks which consequently break in pieces. Although rain seldom occurs in deserts, there are occasional downpours that can result in flash floods. Rain falling on hot rocks can cause them to shatter and the resulting fragments and rubble strewn over the desert floor is further eroded by the wind. This picks up particles of sand and dust and wafts them aloft in sand or dust storms.

World desertification: Desertification has been neatly defined in the text of the United Nations Convention to Combat Desertification (UNCCD) as "land degradation in arid, semi-arid and dry sub-humid regions resulting from various factors, including climatic variations and human activities. The earliest known discussion of the topic arose soon after the French colonization of West Africa, when the Comité d'Etudes commissioned a study on *desséchement progressif* to explore the prehistoric expansion of the Sahara Desert

Wind-blown sand grains striking any solid object in their path can abrade the surface. Rocks are smoothed down, and the wind sorts sand into uniform deposits. The grains end up as level sheets of sand or are piled high in billowing sand dunes. Other deserts are flat, stony plains where all the fine material has been blown away and the surface consists of a mosaic of smooth stones. These areas are known as desert pavements and little further erosion takes place. Other desert features include rock outcrops, exposed bedrock and clays once deposited by flowing water. Temporary lakes may form and salt pans may be left when waters evaporate. There may be underground sources of water in the form of springs and seepages from aquifers. Where these are found, oases can occur. Plants and animals living in the desert need special adaptations to survive in the harsh environment. Plants tend to be tough and wiry with small or no leaves, water-resistant cuticles and often spines to deter herbivory.

Desertification is a type of land degradation in which a relatively dry land region becomes increasingly arid, typically losing its bodies of water as well as vegetation and wildlife.[2] It is caused by a variety of factors, such as climate change and human activities. Desertification is a significant global ecological and environmental problem.

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