

Ecological site VX158X01X005
Naturalized Grassland 50 to 90 inch PZ
Ohia lehua/kikuyugrass
(*Metrosideros polymorpha*/*Pennisetum clandestinum*)

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General information

Provisional. A provisional ecological site description has undergone quality control and quality assurance review. It contains a working state and transition model and enough information to identify the ecological site.

MLRA notes

Major Land Resource Area (MLRA): 158X–Semiarid and Subhumid Low Mountain Slopes

MLRA 158 – Semiarid and Subhumid Low Mountain Slopes This MLRA occurs in the State of Hawaii on the islands of Hawaii, Maui, Lanai, Molokai, Oahu, and Kauai. It consists primarily of nearly level to moderately steep slopes that are dissected in places by gulches. It occurs on leeward, drier sides of the older volcanoes within the Hawaiian Islands. Elevation ranges from sea level to 1600 feet (0 to 490 meters). Geology is largely highly weathered volcanic ash overlying basic igneous rocks. Alluvium derived from basic igneous rocks occurs in some areas. Average annual precipitation typically ranges from 10 to 30 inches (255 to 760 millimeters), rising to over 60 inches (1525 millimeters) in some areas, and mostly occurs from November through March. Much of the rainfall occurs in kona storms during winter. Average annual temperatures range from 69 to 76 degrees F (21 to 24 degrees C), with very little seasonal variation. Soils are mostly Oxisols, Mollisols, and Aridisols with isohyperthermic soil temperature regime and ustic or aridic (torric) soil moisture regimes. Native vegetation is rare and consists mostly of species characteristic of dry forests or savannas, such as lama, koaia, wiliwili, ohe makai, and ulei. Naturalized grasses, such as buffelgrass and guineagrass, and trees, such as koa haole and kiawe, are common.

Classification relationships

This ecological site occurs within Major Land Resource Area (MLRA) 158 - Arid and Semiarid Low Mountain Slopes.

Ecological site concept

This ecological site is located on the leeward sides of West Maui, Molokai, Oahu, Kauai, and, to a very small extent, Lanai. An outlier is located on the north coast of East Maui on some delineations of Honolulu silty clay, 7 to 15 percent slopes (HwC) in an area that receives 120 to 240 inches (3000 to 6000 millimeters) annual rainfall, which is far wetter than the rest of the ecological site. Further field work is needed to determine if these delineations belong in this ecological site. Most of the area lies within MLRA 158, although large parts are in MLRAs 165 and 167. Field work is needed to determine if the MLRA 165 and 167 parts should constitute separate ecological sites or if the MLRA lines need revision. Most of the ecological site is in government ownership. A few examples of this ecological site are accessible near Rte. 340 on the windward coast of West Maui, but most of it is well mauka of the highway. Some areas are accessible along the northern end of Rte. 470 on Molokai, on the outskirts of Wahiawa in central Oahu, and from numerous public highways and roads along the eastern side of Kauai between Kalaheo and Kilauea. The central concept of the Naturalized Grassland 50 to 90 Inch Precipitation Zone is of well drained, moderately deep to very deep soils formed in residuum or alluvium from basic igneous rock or in volcanic ash. Surface soil reaction ranges from extremely acid to strongly acid (pH 4.0 to 5.4); extreme pH of subsurface soils within 30 inches (75 centimeters) of the surface ranges from very strongly acid to moderately acid (pH 4.6 to 5.8). This pH range indicates that aluminum toxicity can be a problem for growth of susceptible plant species. The annual rainfall amounts fall into a range referred to in botanical literature as “mesic,” which is not to be confused with the soil temperature regime of mesic used in Soil Taxonomy. In this case it means moisture conditions that are transitional between dry and moist. Native forests in this ecological site are referred to as “Lowland Mesic Forests” (Wagner et al. 1999; Lowe et al. 2019) or “Evergreen Seasonal Forest” (Hatheway 1952); these forests have high plant diversity, especially for trees. However, this ecological site is not synonymous with Diverse Mesic Forest (Wagner et al. 1999), which occurs on western Kauai and the Waianae Mountains of Oahu and is associated with a separate ecological site. The most common introduced grass is kikuyugrass (*Cenchrus clandestinus*). Forested areas contain many introduced species, with strawberry guava (*Psidium cattleianum*), Java plum (*Syzygium javanicum*), and silk oak (*Grevillea robusta*) among the more common species. Common trees in native forest include olopua (*Nestegis sandwicensis*), hame (*Antidesma pulvinatum*), koa (*Acacia koa*), ohia lehua (*Metrosideros polymorpha*), lama (*Diospyros sandwicensis*), and papala kapau or Australasian catchbirdtree (*Pisonia brunoniana*), among others.

Associated sites

VX158X01X401	Isohyperthermic Ustic Naturalized Grassland Koa haole/guineagrass/glycine (Leucaena leucocephala/Urochloa maxima/Neonotonia wightii) The Isohyperthermic Ustic Naturalized Grassland occurs on the islands of Hawaii, Maui, Molokai, Lanai, Oahu, and Kauai. It forms much of the high elevation boundary of the Naturalized Grassland, 50 to 90 Inch Precipitation Zone. It has warmer soil temperatures, lesser average annual rainfall (30 to 60 versus 50 to 90 inches), supports typical dry forest rather than native forest that is transitional to rainforest, and has different dominant forage grass species (guineagrass versus kikuyugrass and californiagrass) compared to the Naturalized Grassland, 50 to 90 Inch Precipitation Zone.
VX165X01X001	Isothermic Ustic Naturalized Grassland The Naturalized Grassland 30 to 60 Inch Precipitation Zone occurs on West Maui, Molokai, Lanai, Oahu, and Kauai. It has similar soil temperatures, lesser average annual rainfall (30 to 60 versus 50 to 90 inches), similar elevation range, typical native dry forest versus transitional dry-to-moist forest, and a different dominant forage grass species (guineagrass versus kikuyugrass and californiagrass) compared to the Naturalized Grassland, 50 to 90 Inch Precipitation Zone.
VX167X01X001	Oxidic Dissected Lowland The Oxidic Dissected Lowland occurs on the islands of Maui, Oahu, and Kauai and forms most of the higher elevation boundary of the Naturalized Grassland, 50 to 90 Inch Precipitation Zone on Kauai. It has similar soil temperatures, higher average annual rainfall (50 to 150 versus 50 to 90 inches), and similar vegetation compared to the Naturalized Grassland, 50 to 90 Inch Precipitation Zone.

Similar sites

VX159A01X403	Isohyperthermic Udic Naturalized Grassland (Guineagrass / Desmodium) The Isohyperthermic Naturalized Grassland, 60 to 95 Inch Precipitation Zone occurs on the island of Hawaii. It is similar to the Naturalized Grassland, 50 to 90 Inch Precipitation Zone in soil temperature, soil moisture, annual average rainfall, soils, and vegetation, but has a lower elevation range (0 to 1800 feet versus 250 to 3500 feet). The two ecological sites occur in different Major Land Resource Areas.
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Table 1. Dominant plant species

Tree	(1) <i>Metrosideros polymorpha</i>
Shrub	Not specified
Herbaceous	(1) <i>Pennisetum clandestinum</i>

Legacy ID

R158XY005HI

Physiographic features

This ecological site occurs on lava flows on sloping mountainsides of shield volcanoes. Lava flows are aa (loose, cobbly) or pahoehoe (smooth, relatively unbroken).

Table 2. Representative physiographic features

Landforms	(1) Shield volcano > Aa lava flow (2) Shield volcano > Pahoehoe lava flow
Runoff class	Very low to medium
Flooding frequency	None
Ponding frequency	None
Elevation	80 – 1,070 m
Water table depth	150 cm
Aspect	W, NW, N, NE, E, SE, S, SW

Climatic features

(Unless otherwise cited, the information in this section is derived from Western Regional Climate Center, cited 2020).

Summary for this ecological site

Average annual precipitation in this ecological site ranges from 50 to 100 inches (1250 to 2500 mm). Extremes of average annual precipitation range as low as 25 inches (625 mm); some of these low precipitation outliers are at relatively high, cool elevations, which can reduce evapotranspiration. In other places, these low-rainfall outliers grade into other ecological sites. Most of the precipitation occurs from October through April. Average annual temperatures range from 65 to 73 degrees F (18 to 23 degrees C). Rainfall occurs as trade wind showers that drift over or around the mountains from the windward side of the islands and as heavier rainfall during major winter storms. Major storms are important for soil moisture recharge, and the number of major storms is highly variable; drought can result from a winter with few or no storms. Due to the latitude, daylength varies little during the year, resulting in only about a 50 percent variation in solar energy input between June maximum to December minimum; this variation is somewhat less than that found in the continental United States. Conditions are generally clear to moderately cloudy. Sites near the ocean along the northern coast of west Maui are frequently windy, which can stunt vegetation or promote shrubland over forest.

General principles

Air temperature in the Hawaiian Islands is buffered by the surrounding ocean so that the range in temperature through the year is narrow. This creates “iso-” soil temperature regimes in which mean summer and winter temperatures differ by less than 6 degrees C (11 degrees F).

Hawaiian indigenous understanding recognized two seasons during the year: Kau or Kauwela (dry season) when the sun was directly overhead, days are long and warm and tradewinds are stronger and more consistent; Kau started on the first new moon in May when the Pleiades set at sunrise (Handy, 1991). During Ho’oilo (wet season) the sun is declined toward the south, days are shorter, temperatures cooler and winds more variable and generally started with the first new moon in November. Ho’oilo is also the season when extensive low-pressure systems often approach the islands from the west, producing heavy rainstorms that primarily affect the leeward sides, but can envelope the entire island. (Malo, 1903, Handy 1991, Sanderson, 1993). These seasons are mostly consistent with modern observations today. These phenomena of pressure systems and seasonal differences interact with the islands’ topography which together creates the various climate zones and patterns observed in the islands. One such general pattern can be seen in the differences in rainfall amounts between winter and summer; in low elevation dry areas the differences are greater whereas wetter areas exhibit less seasonal variation in rainfall.

The islands lie within the trade wind zone. Moisture is picked up from the ocean y trade winds to an altitude of about 6,000 feet (1850 meters). As the trade winds from the northeast are forced up the islands’ mountains their moisture condenses, creating rain on the windward slopes; the leeward sides of the island receive little of this moisture. The zones of highest rainfall on the windward flanks of the highest mountains (more than 10,000 feet or 3075 meters), which include Mauna Kea, Mauna Loa, and Haleakala, occur at elevations of

2,000 to 4,000 feet (615 to 1230 meters). A temperature inversion that fluctuates between about 5,000 and 7,000 feet (1540 to 2150 meters) on these three highest mountains creates a boundary between lower moist air and higher dry air. Above the inversion, rainfall is scant, skies are usually clear, humidity is low, and temperatures can drop below freezing. On West Maui, Kauai, Molokai, Oahu, and Lanai, where the mountains are all lower than 6,000 feet (1850 meters), the highest rainfall amounts occur along or near the summits. The moist trade winds usually flow across these lower mountains and around the higher mountains. Lanai is sheltered from the trade winds by the much larger island of Maui, putting it in a rain shadow during trade wind weather; rainfall on Lanai is uncharacteristically low for Hawaii.

Besides the trade winds discussed above, other rainfall sources on the Hawaiian Islands include: a) Widespread winter storms that usually approach the islands from the west, producing heavy rainstorms that primarily affect the leeward sides but can envelope much larger areas; b) "Naulu storms" (Leopold 1948) caused by local convergence of sea breezes and trade winds to produce summertime cumulus clouds, resulting in infrequent, short-duration, high-intensity rainfall and afternoon shade over leeward dry areas; and c) Fog drip, particularly important to areas with relatively low rainfall, that adds a significant amount of water to areas where clouds intersect mountains (Juvik and Nullet 1993; Western Regional Climate Center).

The heaviest rains are brought by winter storms. The greatest amounts of storm rainfall do not always occur in areas with the highest average rainfall, and a storm may bring half of the mean annual rainfall to a dry area in one day.

Table 3 Representative climatic features

Frost-free period (characteristic range)	370 days
Freeze-free period (characteristic range)	370 days
Precipitation total (characteristic range)	1,270-2,540 mm
Frost-free period (actual range)	
Freeze-free period (actual range)	
Precipitation total (actual range)	640-2,540 mm
Frost-free period (average)	
Freeze-free period (average)	
Precipitation total (average)	1,910 mm

Influencing water features

This ecological site is intersected by small to medium size, perennial or seasonal streams that have cut gulches into the landscape. The gulches contain plant species found in the rest of the ecological site.

Soil features

This ecological site is correlated with soil series and their phases that occur on multiple islands and are classified in a variety of soil orders. However, they share certain characteristics. They are all well drained. They are in the moderately deep (20 to 40 inches or 50 to 100 centimeters), deep (40 to 60 inches or 100 to 150 centimeters), or very deep (deeper than 60 inches or 150 centimeters) classes. Most of the soils formed in place in residuum of basic igneous rock or alluvium derived from basic igneous rock and are relatively old and weathered; they are classified in the soil orders Oxisols and Ultisols. Two soils formed in volcanic ash deposits; one is classified in the

order Andisols and one has some andic properties. Both are highly weathered relative to Andisols in general. One soil is a Mollisol; it is discussed below.

Surface soil reaction ranges from extremely acid to strongly acid (pH 4.0 to 5.4). Extreme pH of subsurface soils within 30 inches (75 centimeters) of the surface ranges from very strongly acid to moderately acid (pH 4.6 to 5.8); one soil has subsoil that is slightly acid (pH 6.1). Soil temperature regimes are isohyperthermic (very warm) to isothermic (warm), and a soil moisture regimes range from ustic (in normal years, dry for more than 90 cumulative days but less than 180 days) to udic ((in most years, not dry for as long as 90 cumulative days). These ranges of soil temperature and moisture fall in the middle range between hot-dry and cool-wet that produces the distinctive vegetation environment referred to botanically as "mesic."

HONOLUA, LEILEHUA, and OLELO soils are classified as Humults, in the Ultisols soil order. The unique properties common to Ultisols are an argillic horizon (containing clay translocated from overlying horizons) and a low supply of bases, particularly in the lower horizons. The cation-exchange capacity in Ultisols is moderate or low. The decrease in base saturation with increasing depth reflects cycling of bases to the surface by plants or additions from fertilizers. In Ultisols that have not been cultivated, the highest base saturation is normally in the few centimeters directly beneath the surface. The clayey horizons can retain substantial amounts of water, much of it available to plants. Ultisols in the suborder Humults have at least 1.5 percent organic matter in the upper part of the argillic horizon, as defined in the 1972 Soil Survey. Ultisols tend to form in moist climates that promote weathering of soil materials and leaching of base cations, resulting in strongly to extremely acid soils. Many Ultisols in Hawaii are presently in seasonally dry climates; their ultic characteristics formed under wetter ancient climates.

Honolua soils have an umbric surface horizon, indicating high organic matter content that has good water-holding and root penetration characteristics. Concentrations of base nutrient cations are low. Honolua has pH ranging from 5.0 to 5.1, which is just low enough to induce some aluminum toxicity to non-adapted plant species. The organic matter in the umbric horizon will ameliorate this toxicity by binding up soluble aluminum. Plant-available phosphorus is likely to be low because of formation of solid aluminum-phosphorus compounds.

Leilehua soils have an umbric surface horizon, indicating high organic matter content that has good water-holding and root penetration characteristics. Concentrations of base nutrient cations are very low. Honolua has pH ranging from 4.6 to 4.8, which is low enough to induce aluminum toxicity to non-adapted plant species. The organic matter in the umbric horizon will ameliorate this toxicity by binding up soluble aluminum to an extent. Plant-available phosphorus is low because of formation of solid aluminum-phosphorus compounds. The subsurface has a kandic horizon, which has very low cation exchange capacity. The mineralogy of this soil is ferruginous, which means much of the mineral portion of the soil consists of iron oxides; these soils are low in nutrient content and fix phosphorus in forms unavailable to plants.

Olelo soils are similar to Leilehua soils except the mineralogy is parasesquic rather than ferruginous, so plant nutrient conditions are not as bad. Also, Olelo soils occur at higher, cooler elevations than Leilehua soils. Plant roots in this soil are concentrated in the upper 4 inches (10 centimeters) due to high bulk density and poor soil structure just below the surface horizon.

PAALOA and PUHI soils are classified as Oxisols. Oxisols are more highly weathered than other soils; they have a deep, subsurface oxic horizon dominated by clay-size particles of iron and aluminum hydrous oxides. Plant nutrients have been largely leached out of the soil. At low pH, phosphorus is adsorbed onto the oxides, making it largely unavailable to plants, and the ability to retain cation nutrients such as calcium, magnesium, and potassium against leaching is low. Both soils have surface pH of 5 or higher, so aluminum toxicity is unlikely to be a problem, and the high organic matter contents in the surface soils ameliorate aluminum toxicity. Paaloa soils develop a root mat at depth of about 17 inches (42 centimeters). There is no apparent physical root obstructing layer in the soil description. Lack of good root growth below this depth may be due to aluminum toxicity associated with the low subsurface pH that goes as low as 4.7.

NIULII soils are Andisols; NAIWA soils are Inceptisols with Andic properties. They formed in volcanic ash and are old and weathered enough to have low soil pH. Naiwa soils have surface pH of 5.3 and subsurface pH as low as 4.8, so aluminum toxicity risk is borderline. Niulii soils have surface pH of 4.0 and subsurface pH as high as 5.8, so aluminum toxicity risk is high in the surface, although probably offset by high organic matter contents. Niulii soils at the highest elevation range often have fog and cloud cover.

The volcanic ash soils of Hawaii are derived mostly from basaltic ash that varies relatively little in chemical composition (Hazlett and Hyndman 1996; Vitousek 2004)). Most of these volcanic ash soils are classified today as Andisols, which have these "andic" characteristics: ion exchange capacity that varies with pH, but at low pH mostly retaining anions such as nitrate; high phosphorus adsorption, which restricts phosphorus availability to plants; excellent physical properties (low bulk density, good friability, weak stickiness, stable soil aggregates) for cultivation, seedling emergence, and plant root growth; resistance to compaction and an ability to recover from compaction following repeated cycles of wetting and drying; and high capacity to hold water that is available to plants. These characteristics are due to the properties of the parent material, the clay-size noncrystalline materials formed by weathering, and the soil organic matter accumulated during soil formation (Shoji et al. 1993).

KAWAIHAPAI soils are classified as Mollisols. Only one phase of this soil, Kawaihapai silty clay loam, 2 to 7 percent slopes (KlcB), is correlated with this ecological site; all other phases are in R158XY003HI Isohyperthermic Ustic Naturalized Grassland. This phase is noted in the Soil Survey as unique among the series, occurring at higher, cooler elevations, having much lower pH (5.3 to 5.8), and having higher amounts of soil moisture because it occurs in alluvium in narrow drainageways where it receives runoff from surrounding areas. The important properties of Mollisols are a combination of a relatively thick, dark surface horizon (mollic epipedon) that does not

become hard when dry, a dominance of calcium among the extractable cations, and a dominance of crystalline clay minerals of moderate or high cation-exchange capacity. These properties are conducive to plant growth. Although Mollisols usually form under grass in seasonally dry climates, they can form under a forest ecosystem. Although today this phase is largely in kikuyugrass and kaimi clover, the original native vegetation would have been forest.

Adjoining the soils described above are areas mapped as MISCELLANEOUS AREAS. By definition, they have little or no soil and support little or no vegetation. In the Five Islands Soil Survey upon which this ecological site is based, Miscellaneous Areas are extensive, and most were mapped by low-intensity reconnaissance methods that provide less-detailed information than that presented for soil series and their phases. In many cases, however, Miscellaneous Areas in Maui, Molokai, Lanai, Oahu, and Kauai are moderately- to well-vegetated and/or contain plant and animal species of interest to conservationists. They are either extremely difficult to access or were not considered important enough at the time of this survey to warrant full expenditure of resources. They are described in the following paragraphs.

ROCK LAND (rRK) ROCK LAND (rRK) occurs on parent materials of basalt or andesite. Rock cover on the surface ranges from 25 to 90 percent; soils are very shallow (less than 10 inches or 25 centimeters). Near this ecological site it occurs mostly in gulches created by ephemeral streams. Vegetation is generally sparse, but in some spots, vegetation is dense due to localized accumulations of soil and extra moisture from seasonal stream flows. Common plant species are Java plum (*Syzygium cumini*), christmasberry (*Schinus terebinthifolius*), lantana (*Lantana camara*), molassesgrass (*Melinis minutiflora*), and kukui (*Aleurites moluccana*).

ROCK OUTCROP (rRO) ROCK OUTCROP (rRO) has exposed bedrock covering more than ninety percent of the surface. Small areas of lithified coral sand occur on Kauai, Oahu, Lanai, and Molokai. Gulches on Kauai support sparse vegetation on steep sides and denser vegetation in gulch bottoms. Gulch sides on Maui, Molokai, and Lanai are sparsely vegetated; bottoms can be sparse or moderately vegetated.

ROUGH BROKEN LAND (rRR) ROUGH BROKEN LAND (rRR) occurs on very steep sides of gulches and mountainsides. Soil amounts and characteristics are variable; beneath the soil is soft weathered rock. Most occurrences in the vicinity of this ecological site appear to support substantial vegetation cover. Common plant species are common guava (*Psidium guajava*), Natal redtop (*Melinis repens*), bermudagrass (*Cynodon dactylon*), koa haole (*Leucaena leucocephala*), and molassesgrass (*Melinis minutiflora*). Active soil erosion is common.

ROUGH BROKEN AND STONY LAND (rRS) ROUGH BROKEN AND STONY LAND (rRS) occurs only on Maui in very steep, stony gulches. Some soil is present in variable amounts. It generally supports shrubs, small trees, and grass with a significant amount of bare ground.

ROUGH MOUNTAINOUS LAND (rRT) occurs on very steep gulches and narrow ridges; slopes are often greater than 60 percent. Soils often occur over highly-weathered rock (saprolite); this saprolite is usually permeable to roots. Soils are shallow (20 inches or 50 centimeters) and sometimes very shallow (10 inches or 25 centimeters). In wetter areas and on ridgetops the soils are similar to Amalu and Olokui series, which have gleyed subsurface horizons caused by anaerobic conditions. Vegetation is generally dense and often consists of native species such as ohia lehua (*Metrosideros polymorpha*), uluhe fern (*Dicranopteris linearis*), tree ferns (*Cibotium* spp.), and pukiaue (*Leptecophylla tameiameia*). Because this land type is rather inaccessible, it often harbors rare plant species. Some common introduced species occurring here are kukui (*Aleurites moluccana*), lantana (*Lantana camara*), and hilograss (*Paspalum conjugatum*).

STONY BLOWN-OUT LAND (rSN) occurs only on Lanai. It occurs on knolls and in gulches. The soil has eroded down to stones, boulders, and rock outcrop over soft, highly weathered rock. It is sparsely vegetated by introduced species such as molassesgrass (*Melinis minutiflora*), dallisgrass (*Paspalum dilitatum*), lantana (*Lantana camara*), and Natal redtop (*Melinis repens*).

Table 4. Representative soil features

Parent material	(1) Residuum – igneous rock (2) Alluvium – igneous rock
Surface texture	(1) Silty clay (2) Clay (3) Silty clay loam
Drainage class	Well drained

Permeability class	Moderate to moderately rapid
Soil depth	80 – 190 cm
Surface fragment cover <=3"	Not specified
Surface fragment cover >3"	Not specified
Available water capacity (0-101.6cm)	10.67 – 11.94 cm
Soil reaction (1:1 water) (0-50.8cm)	0 – 5.4
Subsurface fragment volume <=3" (Depth not specified)	Not specified
Subsurface fragment volume >3" (Depth not specified)	Not specified

Ecological dynamics

The information in this ecological site description (ESD), including the state-and-transition model (STM), was developed using archaeological and historical data, professional experience, and scientific studies. The information is representative of a complex set of plant communities. Not all scenarios or plants are included. Key indicator plants, animals, and ecological processes are described to inform land management decisions.

States and community phases within this ecological site were differentiated by inspection of data; ordination programs were not available. They were verified by professional consensus and observation of examples in the field.

Natural Disturbances

The natural (not human-caused) disturbances most important for discussion in this ecological site are natural fires, and wind throw. Natural fires caused by lightning might occasionally occur in the drier portions of this ecological site. Wind throw of vegetation can occur during hurricanes or other high wind events.

Human Disturbances

Human-related disturbances have been much more important than natural disturbances in this ecological site since the arrival of Polynesians and, later, Europeans. These reflected in the State and Transition Model Diagram.

The first humans are believed to have migrated to Hawaii between 1000 and 1260 AD (Allen, 2014, Wilmhurst, 2011). Subsequent migrations and population growth increased so that by 1600 AD at least 80% of all the lands in Hawaii below about 1500 feet (roughly 500meters) in elevation had been extensively altered by humans (Kirch 1982); some pollen core data suggest that up to 100% of lowlands may have been altered (Athens 1997). By the time of European contact late in the 18th century, the Polynesians had developed high population densities and placed large areas under intensive agriculture (Cuddihy and Stone 1990).

Prehistoric native lowland forest disturbance can be attributed to clearing for agriculture by hand or by fire, introduction of new plants and animals, and wood harvesting. Less accessible areas may have been affected by factors such as inadvertently introduced plant diseases

and seed predation the introduced Pacific rat (Athens 1997).

After the arrival of Europeans, documentary evidence attests to accelerated and extensive deforestation, erosion, siltation, and changes in local weather patterns (Kirch 1983) due to more intensive land use, modern tools, and introduction of more plant, animal, and microbe species.

The Polynesians introduced dogs, Pacific rats, and small pigs to the islands. Cattle, sheep, horses, goats, and larger European pigs were introduced in the final decade the 18th century. These animals ranged free on the islands, becoming very numerous and destructive by the early decades of the 19th century.

Through the 20th and into the 21st centuries, increases in human populations with attendant land development, as well as accelerated introduction of non-native mammals, birds, reptiles, amphibians, invertebrates, plants, and microorganisms, have brought about dramatic changes to wild ecosystems in Hawaii. This ecological site evolved without the presence of large mammals or human-caused fires.

The most important human disturbances in the ecological site are clearing for agriculture, domestic and feral ungulate foraging, and invasion by introduced plant and animal species. Much of the area is currently used for agriculture and pasture. Some areas had been cleared in the past and then abandoned; these areas are now dominated by forests of introduced species.

The most common introduced grass is kikuyugrass (*Cenchrus clandestinus*). Forested areas contain many introduced species, with strawberry guava (*Psidium cattleianum*), Java plum (*Syzygium javanicum*), and silk oak (*Grevillea robusta*) among the more common species. Common trees in native forest include olopua (*Nestegis sandwicensis*), hame (*Antidesma pulvinatum*), koa (*Acacia koa*), ohia lehua (*Metrosideros polymorpha*), lama (*Diospyros sandwicensis*), and papala kapau or Australasian catchbirdtree (*Pisonia brunoniana*), among others.

State and transition model

Figure 1. STM for R158XY005 Naturalized Grassland 50 to 90 Inch Precipitation Zone

Additional community tables

Table 5. Community 1.1 plant community composition

Group	Common Name	Symbol	Scientific Name	Annual Production ()	Foliar Cover (%)
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Table 6. Community 1.2 plant community composition

Group	Common Name	Symbol	Scientific Name	Annual Production ()	Foliar Cover (%)
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Table 7. Community 2.1 plant community composition

Group	Common Name	Symbol	Scientific Name	Annual Production ()	Foliar Cover (%)
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Table 8. Community 3.1 plant community composition

Group	Common Name	Symbol	Scientific Name	Annual Production ()	Foliar Cover (%)
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Table 9. Community 4.1 plant community composition

Group	Common Name	Symbol	Scientific Name	Annual Production ()	Foliar Cover (%)
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Table 10. Community 5.1 plant community composition

Group	Common Name	Symbol	Scientific Name	Annual Production ()	Foliar Cover (%)
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Other references

Definitions

These definitions have been greatly simplified for brevity and do not cover every aspect of each topic.

Aa lava: A type of basaltic lava having a rough, jagged, clinkery surface and a vesicular interior.

Alluvial: Materials or processes associated with transportation and/or deposition by running water.

Aquic soil moisture regime: A regime in which the soil is free of dissolved oxygen because it is saturated by water. This regime typically

exists in bogs or swamps.

Aquisalids: These are salty soils in wet areas. Although wet, the dissolved salts make the soils physiologically dry (the chemical activity, or effective concentration, of water is low). Aquisalids typically support plant species that are adapted to these conditions.

Aridic soil moisture regime: A regime in which defined parts of the soil are, in normal years, dry for more than half of the growing season and moist for less than 90 consecutive days during the growing season. In Hawaii it is associated with hot, dry areas with plants such as kiawe, wiliwili, and buffelgrass. The terms aridic and torric are basically the same.

Ash field: a land area covered by a thick or distinctive deposit of volcanic ash that can be traced to a specific source and has well defined boundaries. The term “ash flow” is erroneously used in the Physiographic section of this ESD due to a flaw in the national database.

Ashy: A “soil texture modifier” for volcanic ash soils having a water content at the crop wilting point of less than 30 percent; a soil that holds relatively less water than “medial” and “hydrous” soils.

Available water capacity: The amount of soil water available to plants to the depth of the first root-restricting layer.

Basal area or basal cover: The cross-sectional area of the stem or stems of a plant or of all plants in a stand.

Blue rock: The dense, hard, massive lava that forms the inner core of an aa lava flow.

Bulk density: the weight of dry soil per unit of volume. Lower bulk density indicates a greater amount of pore space that can hold water and air in a soil.

CaCO₃ equivalent: The amount of free lime in a soil. Free lime exists as solid material and typically occurs in regions with a dry climate.

Canopy cover: The percentage of ground covered by the vertical projection downward of the outermost perimeter of the spread of plant foliage. Small openings within the canopy are included.

Community pathway: A description of the causes of shifts between community phases. A community pathway is reversible and is attributable to succession, natural disturbances, short-term climatic variation, and facilitating practices, such as grazing management.

Community phase: A unique assemblage of plants and associated dynamic soil properties within a state.

Dominant species: Plant species or species groups that exert considerable influence upon a community due to size, abundance, or cover.

Drainage class: The frequency, duration, and depth of a water table in a soil. There are seven drainage classes, ranging from “excessively drained” (soils with very rare or very deep water tables) to “well drained” (soils that provide ample water for plant growth but are not so wet as to inhibit root growth) to “very poorly drained” (soils with a water table at or near the surface during much of the growing season that inhibits growth of most plants).

Electrical conductivity (EC): A measure of the salinity of a soil. The standard unit is deciSiemens per meter (dS/m), which is numerically equivalent to millimhos per centimeter (mmhos/cm). An EC greater than about 4 dS/m indicates a salinity level that is unfavorable to growth of most plants.

Friability: A soil consistency term pertaining to the ease of crumbling of soils.

Gleyed: A condition of soil from which iron has been reduced (in the redox chemistry sense) and removed during soil formation or that saturation with stagnant water has preserved a reduced state. If iron has been removed, the soil is the color of uncoated sand and silt particles. If iron is present in a reduced state, the soil is the color of reduced iron (typically bluish-gray). Redox concentrations (spots of oxidized iron, formerly called mottles are often present.

Hydrous: A “soil texture modifier” for volcanic ash soils having a water content at the crop wilting point of 100 percent or more; a soil that holds more water than “medial” or “ashy” soils.

Ion exchange capacity: The ability of soil materials such as clay or organic matter to retain ions (which may be plant nutrients) and to release those ions for uptake by roots.

Isohyperthermic soil temperature regime: A regime in which mean annual soil temperature is 72 degrees F (22 degrees C) or higher and mean summer and mean winter soil temperatures differ by less than 11 degrees F (6 degrees C) at a specified depth.

Isomesic soil temperature regime: A regime in which mean annual soil temperature is 47 degrees F (8 degrees C) or higher but lower than 59 degrees F (15 degrees C) and mean summer and mean winter soil temperatures differ by less than 11 degrees F (6 degrees C) at a specified depth.

Isothermic soil temperature regime: A regime in which mean annual soil temperature is 59 degrees F (15 degrees C) or higher but lower than 72 degrees F (22 degrees C) and mean summer and mean winter soil temperatures differ by less than 11 degrees F (6 degrees C) at a specified depth.

Kipuka: An area of land surrounded by younger (more recent) lava. Soils and plant communities within a kipuka are older than, and often quite different from, those on the surrounding surfaces.

Major Land Resource Area (MLRA): A geographic area defined by NRCS that is characterized by a particular pattern of soils, climate, water resources, and land uses. The island of Hawaii contains nine MLRAs, some of which also occur on other islands in the state.

Makai: a Hawaiian word meaning “toward the sea.”

Mauka: a Hawaiian word meaning “toward the mountain” or “inland.”

Medial: A “soil texture modifier” for volcanic ash soils having a water content at the crop wilting point of 30 to 100 percent; a soil that holds an amount of water intermediate to “hydrous” or “ashy” soils.

Mollisols: Soils with relatively thick, dark surface horizons, high cation-exchange capacity, high calcium content, that do not become hard or very hard when dry. Mollisols are conducive to plant growth. They characteristically form under grass in climates that are seasonally dry, but can form under forests.

Naturalized plant community: A community dominated by adapted, introduced species. It is a relatively stable community resulting from secondary succession after disturbance. Most grasslands in Hawaii are in this category.

Oxisols: Soils characteristic of humid, tropical or subtropical regions that formed on land surfaces that have been stable for a long time. In Hawaii, they typically occur on islands or parts of islands that have been volcanically inactive for a long time. Oxisols are highly weathered, consist largely of quartz, kaolin clays, and aluminum oxides, and have low ion exchange capacity and loamy or clayey texture.

Pahoehoe lava: A type of basaltic lava with a smooth, billowy, or rope-like surface and vesicular interior.

Parent material: Unconsolidated and chemically weathered material from which a soil is developed.

Perudic soil moisture regime: A very wet regime found where precipitation exceeds evapotranspiration in all months of normal years. On the island of Hawaii, this regime is found on top of Kohala and on parts of the windward side of Mauna Kea.

pH: The numerical expression of the relative acidity or alkalinity of a soil sample. A pH of 7 is neutral; a pH below 7 is acidic and a pH above 7 is basic.

Phosphorus adsorption: The ability of soil materials to tightly retain phosphorous ions, which are a plant nutrient. Some volcanic ash soils retain phosphorus so strongly that it is partly unavailable to plants.

Psamments: Sandy soils that have low water-holding capacity, are susceptible to wind erosion, and typically have ground water deeper than 20 inches (50 centimeters).

Reference community phase: The phase exhibiting the characteristics of the reference state and containing the full complement of plant species that historically occupied the site. It is the community phase used to classify an ecological site.

Reference state: A state that describes the ecological potential and natural or historical range of variability of an ecological site.

Restoration pathway: A term describing the environmental conditions and practices that are required to recover a state that has undergone a transition.

Sodium adsorption ratio (SAR): A measure of the amount of dissolved sodium relative to calcium and magnesium in the soil water. SAR values higher than 13 create soil conditions unfavorable to most plants.

Soil moisture regime: A term referring to the presence or absence either of ground water or of water held at a tension of less than 1500 kPa (the crop wilting point) in the soil or in specific horizons during periods of the year.

Soil temperature regime: A defined class based on mean annual soil temperature and on differences between summer and winter temperatures at a specified depth.

Soil reaction: Numerical expression in pH units of the relative acidity or alkalinity of a soil.

Spodosols: Soils with a spodic B horizon that has an accumulation of black or reddish amorphous materials that have a high pH-

dependent ion exchange capacity, coarse texture, and few base cations. Above the spodic horizon there often is a light-colored albic horizon that was the source of the amorphous materials in the spodic horizon.

State: One or more community phases and their soil properties that interact with the abiotic and biotic environment to produce persistent functional and structural attributes associated with a characteristic range of variability.

State-and-transition model: A method used to display information about relationships between vegetation, soil, animals, hydrology, disturbances, and management actions on an ecological site.

Torric soil moisture regime: See Aridic soil moisture regime.

Transition: A term describing the biotic or abiotic variables or events that contribute to loss of state resilience and result in shifts between states.

Udic soil moisture regime: A regime in which the soil is not dry in any part for as long as 90 cumulative days in normal years, and so provides ample moisture for plants. In Hawaii it is associated with forests in which hapuu (tree ferns) are usually moderately to highly abundant.

Ultisols: Soils that have been intensively leached and weathered. They have a B horizon that has accumulated clay that has translocated there from higher horizons. They have moderate to low cation exchange capacity and low base saturation. The highest base saturation normally is in the few centimeters directly beneath the surface due to cycling of bases by plants.

Ustic soil moisture regime: A regime in which moisture is limited but present at a time when conditions are suitable for plant growth. In Hawaii it usually is associated with dry forests and subalpine shrublands.

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Rangeland health reference sheet

Interpreting Indicators of Rangeland Health is a qualitative assessment protocol used to determine ecosystem condition based on benchmark characteristics described in the Reference Sheet. A suite of 17 (or more) indicators are typically considered in an assessment. The ecological site(s) representative of an assessment location must be known prior to applying the protocol and must be verified based on soils and climate. Current plant community cannot be used to identify the ecological site.

Author(s)/participant(s)	
Contact for lead author	
Date	10/02/2026
Approved by	
Approval date	
Composition (Indicators 10 and 12) based on	Annual Production

Indicators

1. Number and extent of rills:

2. Presence of water flow patterns:

3. Number and height of erosional pedestals or terracettes:

4. Bare ground from Ecological Site Description or other studies (rock, litter, lichen, moss, plant canopy are not bare ground):

5. Number of gullies and erosion associated with gullies:

6. Extent of wind scoured, blowouts and/or depositional areas:

7. Amount of litter movement (describe size and distance expected to travel):

8. Soil surface (top few mm) resistance to erosion (stability values are averages - most sites will show a range of values):

9. Soil surface structure and SOM content (include type of structure and A-horizon color and thickness):

10. Effect of community phase composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:

11. Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site):

12. Functional/Structural Groups (list in order of descending dominance by above-ground annual-production or live foliar cover using symbols: >>, >, = to indicate much greater than, greater than, and equal to):

Dominant:

Sub-dominant:

Other:

Additional:

13. Amount of plant mortality and decadence (include which functional groups are expected to show mortality or decadence):

14. Average percent litter cover (%) and depth (in):

15. Expected annual annual-production (this is TOTAL above-ground annual-production, not just forage annual-production):

16. Potential invasive (including noxious) species (native and non-native). List species which BOTH characterize degraded states and have the potential to become a dominant or co-dominant species on the ecological site if their future establishment and growth is not actively controlled by management interventions. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants. Note that unlike other indicators, we are describing what is NOT expected in the reference state for the ecological site:

17. Perennial plant reproductive capability:
