Ecological site VX164X01X004
Epiaquic Forest

Last updated: 5/08/2025
Accessed: 03/13/2026

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): 164X–Humid and Very Humid Steep and Very Steep Mountain Slopes

This MLRA occurs in the State of Hawaii on the islands of Hawaii, Maui, Molokai, Oahu, and Kauai. It consists primarily of deeply dissected mountainous areas. Elevation ranges from sea level to 7000 feet (0 to 2100 meters). Topography is mostly steep, with ridges, gulches, and canyons, as well as areas of plateau. Underlying geology is fractured, basic, igneous rock (mostly basalt) that is slightly to highly weathered. Over this are found deposits of local volcanic ash, tropospheric dust from Asia, and/or organic deposits. Climate is mostly wet tropical. Average annual precipitation typically ranges from 75 to 250 inches (1875 to 6250 millimeters), with extremes of 30 to 450 inches (750 to 11,250 millimeters). Rainfall is well distributed throughout the year with and enhanced rainy season from November through April. Fog drip can add significant amounts of water to the soil. Average annual temperatures range from 53 to 75 degrees F (12 to 24 degrees C), with very little seasonal variation. Soils are mostly Inceptisols, Andisols, and Histosols with isothermic or isomesic soil temperature regimes. Native vegetation consists of moderate stature rainforests, dwarf forests, and stands of uluhe with emergent shrubs and trees.

Classification relationships

This ecological site occurs within Major Land Resource Area (MLRA) 164 - Humid and Very Humid Steep and Very Steep Mountain Slopes.

Ecological site concept

This ecological site is forest on the moist upper slopes of the East Molokai Mountains,

central Kauai, and a very small area at the top of Lanai. It is mostly within State lands. There is limited access in the area on Lanai. Access on Molokai is limited to trails.

The central concept of the Epiaquic Forest is of poorly drained, shallow soils formed in material weathered from basic igneous rock. The surface consists of layers of gleyed mineral soils over a very hard ironstone sheet at about 10 to 20 inches (25 to 50 centimeters) depth that perches water above it and is a barrier to deeper root penetration. Vegetation is medium-stature rain forest with closed to open canopy dominated by ohia lehua and an understory canopy dominated by hapuu (tree ferns) with some more open areas dominated by sedges. Mean annual rainfall on Molokai ranges from 75 to 160 inches (1875 to 4000 millimeters), from 100 to 200 inches (2500 to 5000 millimeters) on Kauai, and 40 inches (1000 millimeters) on Lanai. Average annual temperature is from 58 to 66 degrees F (15 to 19 degrees C). Elevations on Molokai are about 1500 to 4000 feet (460 to 1230 meters), 400 to 3800 feet (123 to 1170 meters) on Kauai, and 3250 feet (1000 meters) on Lanai. Clouds and fog cover the landscape nearly every day at the higher elevations. which adds significant amounts of water beyond what falls as rain.

Associated sites

VX164X01X001	**Gleyed Soil Forest** The Gleyed Soil Forest occurs on Maui and Molokai; the Epiaquic Forest occurs on Kauai, Molokai and Lanai. Both ecological sites share similar rainfall and temperatures, and are closely associated within a soil
VX158X01X005	**Naturalized Grassland 50 to 90 inch PZ Ohia lehua/kikuyugrass (Metrosideros polymorpha/Pennisetum clandestinum)** The Naturalized Grassland 50 to 90 Inch Precipitation Zone occurs on Kauai, Lanai, Molokai, Maui, and Oahu, while the Epiaquic Forest occurs only on Kauai, Molokai and Lanai. On Molokai, the Naturalized Grassland 50 to 90 Inch Precipitation Zone partially abuts the lowest-elevation boundary of the Epiaquic Forest. The Naturalized Grassland 50 to 90 Inch Precipitation Zone receives lower rainfall, has higher temperatures, is sunnier, and has well drained rather than poorly drained soils. It supports transitional dry-to-moist forest rather than the rainforest with wetness-adapted species of the Epiaquic Forest
VX166X01X501	**Placorthod Forest** The Placorthods Forest occurs on Molokai and Lanai. The Epiaquic Forest occurs on Molokai, Lanai and Kauai. The Placorthods Forest differs from the Epiaquic Forest by having a thinner organic surface horizon, lacking gleyed horizons, generally being well drained rather than poorly drained, having a udic rather than aquic soil moisture regime, and being in the Spodosols soil order rather than the (Aquic) Inceptisols soil order. The Placorthords Forest lacks the number of wetness-adapted plant species found in the Epiaquic Forest.

Similar sites

VX164X01X501	**Sphagnum Peat Dwarf Forest** The Sphagnum Peat Dwarf Forest occurs on Kohala on the island of Hawaii, while the Epiaquic Forest occurs on Kauai, Molokai and Lanai. Both ecological sites have similar climates. The Sphagnum Peat Dwarf Forest has a thick surface layer composed of sphagnum, while the Epiaquic Forest has a thin surface layer of decomposing litter.

Table 1. Dominant plant species

Tree	(1) *Metrosideros polymorpha* (2) *Ilex anomala*
Shrub	(1) *Styphelia tameiameiae*
Herbaceous	(1) *Dicranopteris linearis*

Legacy ID

F164XY004HI

Physiographic features

This ecological site occurs on weathered basaltic lava flows.

Table 2. Representative physiographic features

Landforms	(1) Shield volcano > Plateau
Runoff class	Medium to very high
Flooding frequency	None
Ponding frequency	None
Elevation	457–1,219 m
Slope	3–30%
Water table depth	13–91 cm
Aspect	W, N, E, SE, S, SW

Table 3. Representative physiographic features (actual ranges)

Runoff class	Not specified
Flooding frequency	None to frequent
Ponding frequency	None to frequent
Elevation	122–1,372 m
Slope	3–70%

Water table depth	13–183 cm

Climatic features

Summary for this ecological site
Mean annual rainfall on Molokai ranges from 75 to 160 inches (1875 to 4000 millimeters), from 100 to 200 inches (2500 to 5000 millimeters) on Kauai, and 40 inches (1000 millimeters) on Lanai. Rainfall occurs throughout the year, with the heaviest precipitation occurring from October through April. Landscapes are shrouded in fog or overcast during much of the day throughout the year, which reduces evapotranspiration and adds additional moisture from condensation of fog on vegetation. Average annual temperature is from 58 to 66 degrees F (15 to 19 degrees C). Frost free and freeze free periods are 365 days per year.

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).

The islands lie within the trade wind zone. Significant amounts of moisture are picked up from the ocean by trade winds up to an altitude of more than about 6000 feet (1850 meters). As the trade winds from the northeast are forced up the mountains of the islands their moisture condenses, creating rain on the windward slopes; the leeward sides of the island receive little of this moisture.

Two seasons can be defined during the year: a seven-month winter season from October through April and a five-month summer season from May through September. Summer has warmer temperatures, steadier and stronger trade winds, few widespread rainstorms, and generally lower average monthly rainfall than winter. Differences in rainfall amounts between winter and summer are most marked in low elevation dry areas; wetter areas exhibit less seasonal variation in rainfall.

On the windward sides of the islands, cool, moist air at higher elevations descends toward the ocean where it meets the trade winds; this process brings rainfall, often at night, to lower elevation areas.

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. These major storms occur most frequently between October and March.

Table 4. Representative climatic features

Frost-free period (characteristic range)	365 days

Freeze-free period (characteristic range)	365 days
Precipitation total (characteristic range)	1,905-4,064 mm
Frost-free period (actual range)	
Freeze-free period (actual range)	
Precipitation total (actual range)	1,016-6,350 mm
Frost-free period (average)	365 days
Freeze-free period (average)	365 days
Precipitation total (average)	3,683 mm

Influencing water features

Small headwater streams form within this ecological site. Small ponded areas are scattered within the site. There is considerable lateral movement of water above the ironstone sheet. The National Wetlands Inventory classifies the parts of the area as palustrine forest and scrub-shrub, seasonally to semi permanently flooded. With the exception of Olokui soils the Soil Survey information does not indicate ponding or flooding.

Soil features

This ecological site occurs on Olokui series soils, which are classified as fine, mixed, semiactive, acid, isothermic Humic Epiaquepts, Hulua soils, which are classified as hydrous, amorphic, isothermic Placic Petraquepts, and Koolau soils, which are classified as medial, amorphic, acid, isothermic Alic Epiaquands. They are shallow, poorly drained soils that formed in material weathered from basic igneous rock. The surface horizons have a gleyed matrix with hydromorphic features indicating alternating saturation and drainage of pores and structural planes over a very hard ironstone sheet at about 10 to 20 inches (25 to 50 centimeters) depth that perches water above it and is a barrier to deeper root penetration. There is much lateral seepage above the ironstone sheet. On slopes greater than 15 percent, the ironstone sheet is commonly weakly developed. The soil temperature regime is isothermic. Soil reaction is extremely to very strongly acid (pH 4.1 to 5.2) in the gleyed horizons.

Table 5. Representative soil features

Parent material	(1) Residuum–igneous rock
Surface texture	(1) Gravelly silty clay loam (2) Silty clay
Family particle size	(1) Hydrous (2) Medial
Drainage class	Poorly drained

Permeability class	Very slow
Depth to restrictive layer	41 cm
Soil depth	41–183 cm
Surface fragment cover <=3"	0%
Surface fragment cover >3"	0%
Available water capacity (0-101.6cm)	5.08–12.7 cm
Calcium carbonate equivalent (0-101.6cm)	0%
Electrical conductivity (0-101.6cm)	0 mmhos/cm
Sodium adsorption ratio (0-101.6cm)	0
Soil reaction (1:1 water) (0-101.6cm)	3.5–5.5
Subsurface fragment volume <=3" (0-40.6cm)	3–23%
Subsurface fragment volume >3" (0-40.6cm)	2–20%

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.

Natural Disturbances

Possible natural disturbances are hurricanes, droughts and, in some locations, landslides.

Human Disturbances

Humans arrived in the Hawaiian Islands 1200 to 1500 years ago. Their population gradually increased so that by 1600 AD at least 80% of all the lands in Hawaii below about 1500 feet (roughly 500 meters) in elevation had been extensively altered by humans (Kirch 1982)). This ecological site occurs well above that elevation. However, this ecological site may have been affected by factors such as inadvertently introduced plant diseases and seed predation by 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 decades of the 18th century. These animals ranged free on the islands, becoming very numerous and destructive by the early decades of the 19th century (Henke 1929). The most destructive introduced animals in this remote ecological site have been feral pigs and cattle.

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.

The main disturbances in this ecological site are due to feral pigs, deer, and goats that disturb the soil and directly consume native plants and rats that consume seeds. Some plant species introduced since the arrival of Europeans in Hawaii thrive in this ecological site and can spread rapidly over large areas, competing with native plants. The most abundant invasive plant species are the shrub soapbush or Koster's curse (*Clidemia hirta*) and the small tree strawberry guava (*Psidium cattleianum*). The forb Colombian waxweed (*Cuphea carthagenensis*) is present. West Indian raspberry (*Rubus rosifolius*) is common. Some common introduced and invasive grass and sedges are hilograss (*Paspalum conjugatum*), common rush (*Juncus effusus*), and glenwood grass (*Sacciolepis indica*).

State and transition model

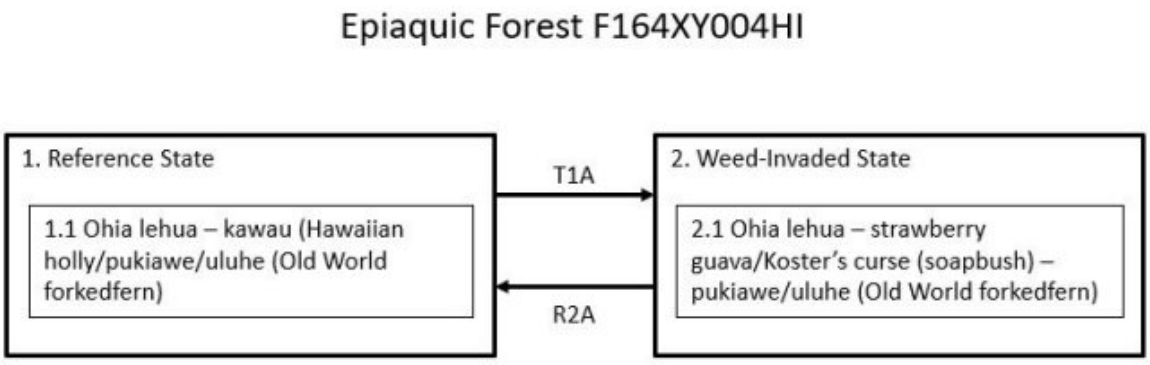

Figure 1. State and Transition Model for the Epiaquic Forest (F164XY004HI).

State 1

Reference State

This state is comprised of one community phase. With disturbance from hurricanes, landslides, or introduced mammals, invasive plants invade the site and native plant species decline in abundance. Invasive plants may invade the site without other disturbances, but the process is much slower.

Community 1.1
Ohia lehua – kawau (Hawaiian holly)/pukiawe/uluhe (Old World forkedfern)

The vegetation of this community phase is rainforest of medium stature and open or closed upper canopy. Lichens, mosses, and epiphytes grow on tree trunks and branches. Ferns are abundant and diverse. Extensive areas with little open canopy are dominated by uluhe fern, shrubs, and tall sedges. Ohia lehua (*Metrosideros polymorpha*), kawau or Hawaiian holly (*Ilex anomala*), and olapalapa or olapa (*Cheirodendron trigynum*) are common overstory tree species; the overstory is typically 20 to 26 feet (6 to 8 meters) tall. Other common tree genera are Melicope, Myrsine, Coprosma, Kadua (Hedyotis), and Psychotria. Common shrubs are plantainleaf dubautia (*Dubautia plantaginea* ssp. plantaginea) and ohelo (*Vaccinium dentatum*). The tree ferns hapuu (*Cibotium glaucum*) and hapuu li (*C. menziesii*) are common.

Dominant plant species

- 'ohi'a lehua (*Metrosideros polymorpha*), tree
- Hawai'i holly (*Ilex anomala*), tree
- pukiawe (*Styphelia tameiameiae*), shrub
- Old World forkedfern (*Dicranopteris linearis*), other herbaceous

State 2
Weed-Invaded State

This state is comprised of one community phase. It comes into being by gradual invasion of introduced species. Disturbance of the soil and direct damage to native plants by introduced ungulates, particularly pigs, goats, and deer, will facilitate the transition to this state.

Community 2.1
Ohia lehua-strawberry guava/Koster's curse (soapbush) - pukiawe/uluhe (Old World forkedfern)

The vegetation consists of low to medium stature trees with a diverse understory. Native species are present but have been partially displaced by introduced species. The most common introduced species are soapbush or Koster’s curse (*Clidemia hirta*) and strawberry guava (*Psidium cattleianum*). West Indian raspberry (*Rubus rosifolius*) is common. Some common introduced and invasive grasses, rushes, and sedges are

hilograss (*Paspalum conjugatum*), common rush (*Juncus effusus*), and glenwood grass (*Sacciolepis indica*).common carpetgrass (*Axonopus fissifolius*), Meyen's flatsedge (*Cyperus meyenianus*), and glenwood grass (*Sacciolepis indica*).

Dominant plant species

- 'ohi'a lehua (*Metrosideros polymorpha*), tree
- strawberry guava (*Psidium cattleianum*), tree
- soapbush (*Clidemia hirta*), shrub
- pukiawe (*Styphelia tameiameiae*), shrub
- Old World forkedfern (*Dicranopteris linearis*), other herbaceous

Transition T1A
State 1 to 2

State 1, the Reference State, transitions to State 2, Weed-Invaded State, by invasion of introduced species. Disturbance by feral deer, goats, and pigs will hasten this process, as will landslides and hurricanes.

Restoration pathway R2A
State 2 to 1

Restoration of State 2 Weed-Invaded State to State 1 Reference State or a facsimile of it may be possible by installing ungulate-proof fence, removing all ungulates, removing introduced plant species, and replanting native species when needed. Long term weed management and fence maintenance would be necessary.

Additional community tables

Other references

ANNOTATED REFERENCES

Armstrong RW. 1973. Atlas of Hawaii. University of Hawai`i Press, Honolulu. General reference for climate, land use, land forms, etc.

Athens JS. Ch. 12 Hawaiian Native Lowland Vegetation, IN Prehistory in Historical Ecology in the Pacific Islands – Prehistoric Environmental and Landscape Change. Kirch, PV and TL Hunt, eds. 1997. Yale U. Press, New Haven. General discussion of effects of prehistoric Polynesians on native lowland vegetation.

Burney DA, HF James, LP Burney, SL Olson, W Kikuchi, WL Wagner, M Burney, D McCloskey, D Kikuchi, FV Grady, R Gage II, and R Nishek. 2001. Fossil evidence diverse biota from Kauai and its transformation since human arrival. Ecological Monographs 71:615-641. Investigation of fossil evidence to trace changes in Hawaiian biota over time; generally applicable to all Hawaiian islands.

Craighill ES and EG Handy. 1991. Native Planters in Old Hawaii – Their Life, Lore, and Environment. Bernice P. Bishop Museum Bulletin 233, Bishop Museum Press, Honolulu, HI Discussion of early agriculture in Hawaii.

Cuddihy LW and CP Stone. 1990. Alteration of Native Hawaiian Vegetation: Effects of Humans, Their Activities and Introductions. Honolulu: University of Hawaii Cooperative National Park Resources Study Unit. General account of human effects on native Hawaiian vegetation.

Deenik J and AT McClellan. 2007. Soils of Hawaii. Soil and Crop Management, Sept. 2007, SCM-20. Cooperativve Extension Service, College of Tropical Agriculture and Human Resources. University of Hawaii at Manoa. Available online at: https://www.ctahr.hawaii.edu/oc/freepubs/pdf/SCM-20.pdf Discussion of soil orders and their practical implications in Hawaii.

Dixon JB and Schulze DG, eds. 2002. Soil Mineralogy with Environmental Applications. Volume 7. Soil Science Society of America. Available online at: https://acsess.onlinelibrary.wiley.com/doi/book/10.2136/sssabookser7 Exhaustive treatment of basics of soil mineralogy and implications for environmental management.

Giambelluca TW and TA Schroeder. 1998. Climate. In Atlas of Hawaii, 3rd edition. SP Juvik, JO Juvik, and RR Paradise, eds. pp. 49-59. Honolulu: University of Hawaii Press. Standard geographical reference work for Hawaii.

Hawaii Division of Forestry and Wildlife. 1991. Olokui Natural Area Reserve Management Plan. Department of Land & Natural Resources, Natural Area Reserves System Program, State of Hawaii. Botanical survey of northern aspect of this ecological site on Molokai.

Hazlett RW and DW Hyndman. 1996. Roadside Geology of Hawaii. Mountain Press Publishing Company, Missoula MT. General account of geologic history of Hawaii.

Henke LA. 1929. A Survey of Livestock in Hawaii. Research Publication No. 5. University of Hawaii, Honolulu. Early assessment and history of effects of European livestock on Hawaiian ecosystems.

Imada, C. 2012. Hawaiian Native and Naturalized Vascular Plants Checklist (December 2012 update). Bishop Museum Technical Report 60. Bishop Museum Press, Honolulu. Constantly-updated list of vascular plants of Hawaii, including latest nomenclature and species occurrences on each island.

Jacobi JD. 1989. Vegetation Maps of the Upland Plant Communities on the Islands of Hawaii, Maui, Molokai, and Lanai. Technical Report 68. Cooperative National Park Resources Studies Unit, University of Hawaii at Manoa and National Park Service. Shapefiles of upland vegetation communities with canopy types, stature, environment

types, and general species information.

Juvik JO and D Nullet. 1993. Relationships between rainfall, cloud-water interception, and canopy throughfall in a Hawaiian montane forest. In: Tropical Montane Cloud Forests. Proc. Int. Sym., San Juan, PR. Hamilton LS, JO Juvik, and FN Scatena, eds. East-West Center. Discussion of importance of fog drip to total precipitatiion in a montane forest.

Kirch PV. 1982. The impact of the prehistoric Polynesians in the Hawaiian ecosystem. Pacific Science 36(1):1-14. General discussion of effects of prehistoric Polynesians on native vegetation.

Kirch PV. 1985. Feathered Gods and Fishhooks: An Introduction to Hawaiian Archaeology and Prehistory. Honolulu: University of Hawaii Press. General discussion of effects of prehistoric Polynesians on native vegetation.

Kirch PV. 2000. On the Road of the Winds: An Archaeological History of the Pacific Islands Before European Contact. Berkeley: University of California Press. General discussion of effects of prehistoric Polynesians on native vegetation.

Little EL Jr. and RG Skolmen. 1989. Common Forest Trees of Hawaii (Native and Introduced). US Department of Agriculture-US Forest Service Agriculture Handbook No. 679. (out of print). Available at www.fs.fed.us/psw/publications/documents/misc/ah679.pdf Information on common native and introduced tree species in Hawaii. Especially useful for introduced species.

Mueller-Dombois D and FR Fosberg. 1998. Vegetation of the Tropical Pacific Islands. Springer-Verlag New York, Inc. General account of tropical Pacific Island vegetation, with section on Hawaii. Discussion of likely effect of stoniness on soil moistue storage in dry habitats.

Palmer DD. 2003. Hawaii’s Ferns and Fern Allies. University of Hawaii Press, Honolulu. Standard reference for Hawaiian ferns and fern allies.

Pratt HD. 1998. A Pocket Guide to Hawaii’s Trees and Shrubs. Mutual Publishing, Honolulu. Useful guide to common tree and plant species, with color photos.

Reppun F, Silva JHS, Wong K, and Deenik JL. 2017. A Soil Phosphorus Primer for Hawaiian Soils. Soil and Crop Management, August 2017, SCM-33. College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa. Available online at: https://www.ctahr.hawaii.edu/oc/freepubs/pdf/SCM-33.pdf Practical discussion of soil phosphorus for Hawaii.

Ripperton JC and EY Hosaka. 1942. Vegetation zones of Hawaii. Hawaii Agricultural Experiment Station Bulletin 89:1-60. Broad-scale map of vegetation zones in Hawaii.

Rock JF. The Indigenous Trees of the Hawaiian Islands. 1st edition 1913, reprinted 1974, Charles E. Tuttle Company, Rutland, VT and Tokyo, Japan. Very useful account observations of native vegetation in Hawaii from early 20th century. Can be paired with GIS layer of place names to locate species observations.

Shoji SD, M Nanzyo, and R Dahlgren. 1993. Volcanic Ash Soils: Genesis, Properties and Utilization. Elsevier, New York. Detailed discussion of volcanic ash soils. Not specific to Hawaii, but very informative.

Silva JA and R Uchida, eds. 2000. Plant Nutrient Management in Hawaii's Soils, Approaches for Tropical and Subtropical Agriculture. College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa. Available online at: https://www.ctahr.hawaii.edu/oc/freepubs/pdf/pnm0.pdf Practical discussion of plant nutrient management for Hawaii.

Sohmer SH and R Gustafson. 2000. Plants and Flowers of Hawaii. University of Hawaii Press, Honolulu. A good general discussion, with color photographs, primarily of native Hawaiian plants and vegetation types.

Soil Survey Staff. 2014. Soil Taxonomy, Twelfth Edition. USDA – NRCS. Standard book of soil taxonomy; useful for terminology and interpretation of soils, also.

Steadman DW. 1995. Prehistoric extinctions of Pacific island birds: biodiversity meets zooarchaeology. Science 267:1123-1131. Discussion of loss of many bird species, including flightless birds.

USDA-NRCS-PIA Threatened & Endangered Species GIS files. Not publicly available. Specific locations of observations of many native Hawaiian plant species.

USDA-NRCS. 2011. Soil Survey Laboratory Information Manual. Soil Survey Investigations Report No. 45, Version 2.0. National Soil Survey Center, Lincoln, Nebraska.

USDA-NRCS. 2006. Major Land Resource Regions. USDA Agriculture Handbook 296. http://soils.usda.gov/MLRAExplorer Description of MLRAs of Hawaii.

USDA-NRCS. Island of Hawaii Soil Surveys 801 and 701. Available online at https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm The latest NRCS soil survey for the island of Hawaii.

USDA-SCS. 1972. Soil Survey of Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawaii. Foote DE, Hill EL, Nakamura S, and F Stephens, in cooperation with The University of Hawaii Agricultural Experiment Station. The latest NRCS soil survey for these islands. Some of the taxonomic names are outdated.

USDI-USGS. 2006. A GAP Analysis of Hawaii. Final Report and Data. GIS map of

vegetation types and land use in Hawaii based on remote sensing. Very general, occasionally inaccurate, but useful.

Vitousek P. 2004. Nutrient Cycling and Limitation: Hawai`i as a Model Ecosystem. Princeton University Press, Princeton and Oxford. Discussion of development of soils, soil nutrients, and plant species in Hawaiian Archipelago.

Wagner WL, DR Herbst, and SH Sohmer. 1999. Manual of the Flowering Plants of Hawaii, Revised Edition. Bishop Museum Press, Honolulu. Standard reference of flowering plants of Hawaii.

Western Regional Climate Center, cited 2020. Climate of Hawaii. Available: https://wrcc.dri.edu/Climate/narrative_hi.php Detailed summary of climate of Hawaiian Islands.

Whistler, WA. 1995. Wayside Plants of the Islands: A Guide to the Lowland Flora of the Pacific Islands. Isle Botanica, Honolulu. Reference of common introduced plant species in lowland areas of the Pacific Islands including Hawaii; with color photographs.

Wood, KR. 1998. Personal Observations and Checklist of the Vascular Plants of Upper Mapulehu Valley, Molokai (East Side/2400-3000 Feet Elevation). National Tropical Botanical Garden Biological Report. Technical Report - March 1998. Detailed review of plant species and general background for this ecological site, based on field work. Focus was on part of southern aspect of Molokai Mountains.

DEFINITIONS

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.

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

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 and duration 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.

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.

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.

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.

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.

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

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.

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 or a soil.

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.

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.

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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Acknowledgments

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Mick Castillo
Michael Constantinides, NRCS-PIA
Susan Cordell, USFS
Gordon Cran, Kapapala Ranch
David Foster, volunteer
JB Friday, UH Forestry Extension
Rick Gordon
Basil Hansen, The Nature Conservancy
Flint Hughes, USFS
Chris Jasper, NRCS Soil Survey
Mel Johansen, The Nature Conservancy
Kathy Kawakami, US Army Pohakuloa Training Ground
Rhonda Loh, Volcanoes National Park
Kamehameha Schools/Bishop Estate
Miles Nakahara, Hawaii DOFAW
Laura Nelson, The Nature Conservancy and NRCS
Patrick Niemeyer, NRCS Soil Survey
Billy Paris, rancher
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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	03/13/2026
Approved by	Kendra Moseley
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:**