USDA Natural Resources
Conservation Service

Ecological site VX167X01X002
Flooded Alluvium

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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): 167X–Humid Oxidic Soils on Low and Intermediate Rolling Mountain Slopes

This MLRA occurs in the State of Hawaii on the windward, wetter sides of the islands of Kauai, Oahu, and Maui. Elevation ranges from near sea level to 2,000 feet (0 to 610 meters) with extremes up to 3,100 feet (0 to 945 meters). Topography is rolling mountain slopes that have been eroded by steep-sided gulches. In most of the area, volcanic ash is underlaid by basic igneous rocks, although in some areas volcanic ash was deposited over cinders (USDA-NRCS, 2006). In other areas alluvial sediments occur on bottom lands and low terraces along streams. In some small areas, the dominant geology is influenced by tropospheric dust. Average annual precipitation in most of the area ranges from 50 to 114 inches (1,270 to 2,896 millimeters); extremes range from 20 inches to 247 inches (508 to 6,274 millimeters) (Giambelluca et al., 2013). Rainfall is well-distributed throughout the year with an enhanced rainy season from November through April. Average annual air temperatures range from 72 to 77 degrees F (22 to 25 degrees C); extremes range from 61 to 82 degrees F (16 to 28 degrees C) (Giambelluca et al., 2014). The dominant soil orders are Ultisols, Oxisols, Inceptisols, and Andisols with Isohyperthermic soil temperature regimes and ustic, udic, and occasionally perudic soil moisture regimes (USDA-NRCS, 2006). Native vegetation consists of medium to tall statured rain forest and open bogs.

Classification relationships

This ecological site occurs within Major Land Resource Area (MLRA) 167 - Humid Oxidic Soils on Low and Intermediate Rolling Mountain Slopes.

The Aha Moku System, which dates back to the 9th century and has been passed down through oral tradition and generational wisdom, effectively sustains Hawaii's natural ecosystems and environment (DLNR, 2024). This site-specific and resource-based approach balances land and ocean resources essential for fostering healthy, thriving communities. Grounded in Native Hawaiian generational knowledge, the Aha Moku System emphasizes community consultation to prioritize the health and welfare of Hawaii's natural and cultural resources. It is rooted in the concept of 'ahupua'a, the traditional system of land and ocean management in Hawaii. For collaboration, this ecological framework encompasses the following mokus:

Moku Acres on Kauai: Puna (4,012), Halele'a (3,310), Kona (1,436), and Ko'olau (656).

Moku Acres on Oahu: Ko'olaupoko (2,947), Kona (522), Ko'olauloa (408), Ewa (355), and Wai'anae (170).

Ecological site concept

This ecological site occurs primarily on the windward sides of Kauai and Oahu; there are a few small occurrences on the leeward sides of those islands. Much of the land is in private ownership. The public road network provides access to most of the ecological site. Most of the area is used for crops, livestock grazing, residential development, or is in forests consisting mostly of introduced species (USDI-USGS, 2006).

The central concept of the Flooded Alluvium ecological site is of somewhat poorly to poorly drained, moderately deep to deep alluvial soils in flood plains along stream courses. The alluvium originated in weathered basic igneous materials in uplands. Soils are Mollisols and Inceptisols orders, and all but one are endosaturated, meaning the soil is saturated with water in all layers from the upper boundary of saturation to a depth of 78 inches (200 centimeters) or more from the mineral soil surface. The most common introduced grass is para grass or Californiagrass (*Urochloa mutica*). Forested areas contain many introduced species (USDA-SCS, 1972).

Associated sites

VX158X01X005	**Naturalized Grassland 50 to 90 inch PZ Ohia lehua/kikuyugrass (Metrosideros polymorpha/Pennisetum clandestinum)** The Naturalized Grassland 50 to 90 Inch Precipitation Zone Ecological Site (R158XY005HI) adjoins this ecological site on Kauai and Oahu. It occurs on the uplands around the dissecting stream floodplains of this ecological site where it has highly weathered soils and conditions are cooler and moister than R158XY401HI (in the row above). R158XY005HI lacks the additonal water from flooding and shallow water tables found in this ecological site.

VX167X01X001	**Oxidic Dissected Lowland** The Oxidic Dissected Lowland Ecological Site (R167XY001HI) adjoins this ecological site on Kauai and Oahu. It occurs on the uplands around the dissecting stream floodplains of this ecological site. Climates are identical where these sites co-occur, but R167XY001HI lacks the additional water from flooding and shallow water tables found in this ecological site.
VX158X01X401	**Isohyperthermic Ustic Naturalized Grassland Koa haole/guineagrass/glycine (Leucaena leucocephala/Urochloa maxima/Neonotonia wightii)** The Isohyperthermic Ustic Naturalized Grassland Ecological Site (R158XY401HI) adjoins this ecological site on Kauai and Oahu. It occurs on the uplands around the dissecting stream floodplains of this ecological site. Climates are identical where these sites co-occur, but R158XY401HI lacks the additional water from flooding and shallow water tables found in this ecological site.

Table 1. Dominant plant species

Tree	Not specified
Shrub	Not specified
Herbaceous	(1) *Urochloa mutica*

Legacy ID

R167XY002HI

Physiographic features

This ecological site occurs on shield volcanoes on alluvial soils in flood plains along stream courses (USDA-SCS, 1972).

Table 2. Representative physiographic features

Landforms	(1) Shield volcano > Alluvial flat (2) Shield volcano > Alluvial fan (3) Shield volcano > Flood plain (4) Shield volcano > Stream
Runoff class	Very low
Flooding frequency	Rare to frequent
Ponding frequency	Rare to frequent
Elevation	0–229 m
Slope	0–6%
Water table depth	107–183 cm

Aspect	N, NE, E, SW

Table 3. Representative physiographic features (actual ranges)

Runoff class	Not specified
Flooding frequency	Not specified
Ponding frequency	Not specified
Elevation	0–427 m
Slope	Not specified
Water table depth	15–183 cm

Climatic features

Summary for this ecological site
Rainfall statistics were determined from University of Hawaii's Rainfall Atlas Raster Data (Giambelluca et al., 2013). Most of the precipitation falls from October through April. Representative (20th and 80th percentiles) values for annual average precipitation range from 50 to 105 inches (1,270 to 2,667 millimeters) while actual (10th and 90th percentiles) values for annual average precipitation range from 42 to 121 inches (1,067 to 3,073 millimeters). Extreme values range from 20 to 180 inches (508 to 4,572 millimeters). The mean annual precipitation is 78 inches (1,981 millimeters) and the median annual average precipitation is 75 inches (1,905 millimeters).

Temperature statistics were determined from University of Hawaii's Surface Temperature Raster Data (Giambelluca et al., 2014). Representative (20th and 80th percentiles) values for annual temperatures range from 72 to 77 degrees F (22 to 25 degrees C) while actual (10th and 90th percentiles) values for annual temperatures range from 72 to 81 degrees F (22 to 27 degrees C). Extreme values range from 68 to 82 degrees F (20 to 28 degrees C). The mean annual temperature is 75 degrees F (24 degrees C) and the median annual temperature is 73 degrees F (23 degrees C).

The data presented in the climate normals tables below are from the Western Region Climate Center (Western Regional Climate Center, 2020). The available climate station data are most representative of the low and moderate precipitation areas of this ecological site. I used these data because they provide a reasonable approximation of the University of Hawaii data presented above.

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: Kau or Kauwela (dry season), and Ho`oilo (wet season). During Kau, the sun is directly overhead, days are long and warm, and the trade winds are stronger and more consistent; Kau started on the first new moon in May when the Pleiades set at sunrise (Handy et al., 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 et al., 1991; Sanderson, 1993). Differences in rainfall amounts between winter and summer are most marked in low elevation dry areas; wetter areas exhibit less seasonal variation in rainfall (USDA-SCS, 1972; Western Regional Climate Center, 2020).

The islands lie within the trade wind zone. Moisture is picked up from the ocean by trade winds to an altitude of about 6,000 feet (1,829 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. Above the inversion, rainfall is scant, skies are usually clear, humidity is low, and temperatures can drop below freezing (USDA-SCS, 1972; Western Regional Climate Center, 2020).

On Kauai and Oahu, where the mountains are all lower than 6,000 feet (1,829 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 (USDA-SCS, 1972).

Besides the trade winds discussed above, other rainfall sources on the Hawaiian Islands include: a) "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 b) 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, 2020).

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 (USDA-SCS, 1972; Western Regional Climate Center, 2020).

Table 4. Representative climatic features

Frost-free period (characteristic range)	365 days
Freeze-free period (characteristic range)	365 days
Precipitation total (characteristic range)	1,270-2,667 mm
Frost-free period (actual range)	365 days

Freeze-free period (actual range)	365 days
Precipitation total (actual range)	1,067-3,073 mm
Frost-free period (average)	365 days
Freeze-free period (average)	365 days
Precipitation total (average)	1,981 mm

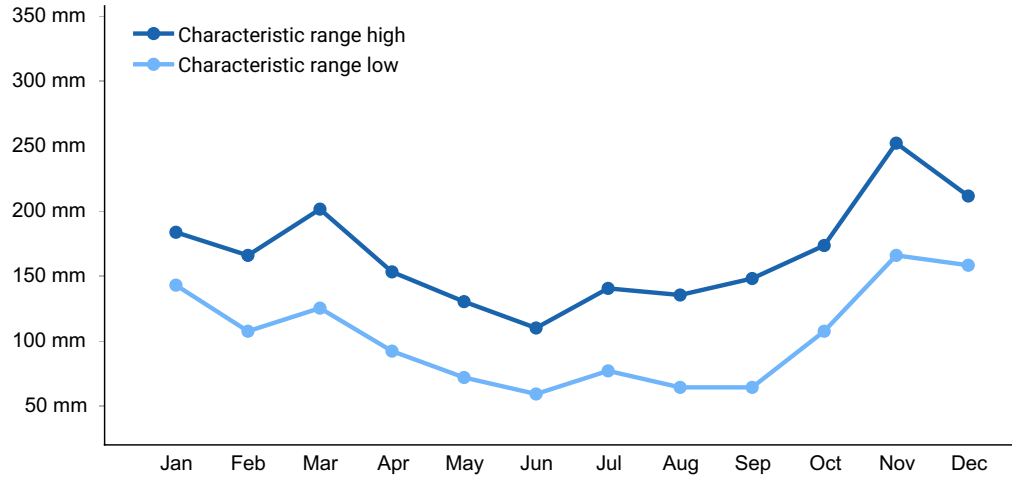

Figure 1. Monthly precipitation range

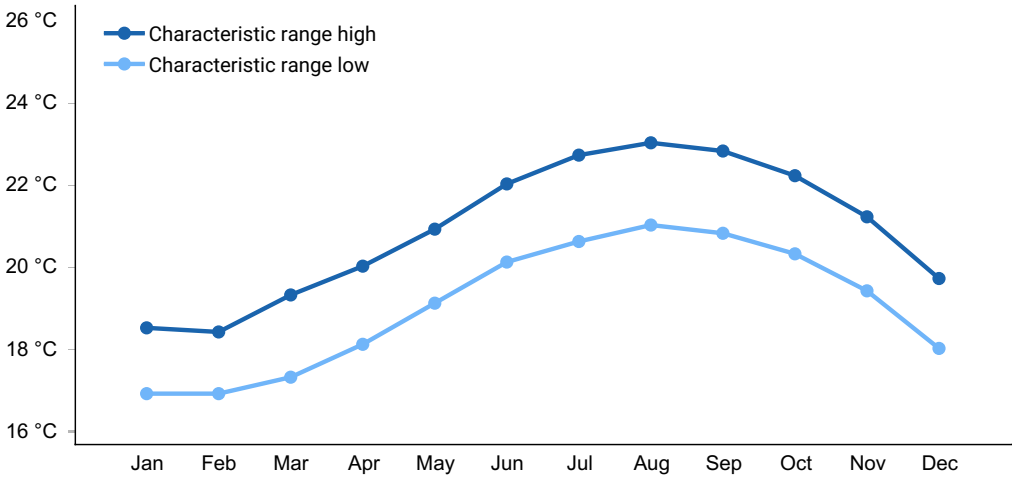

Figure 2. Monthly minimum temperature range

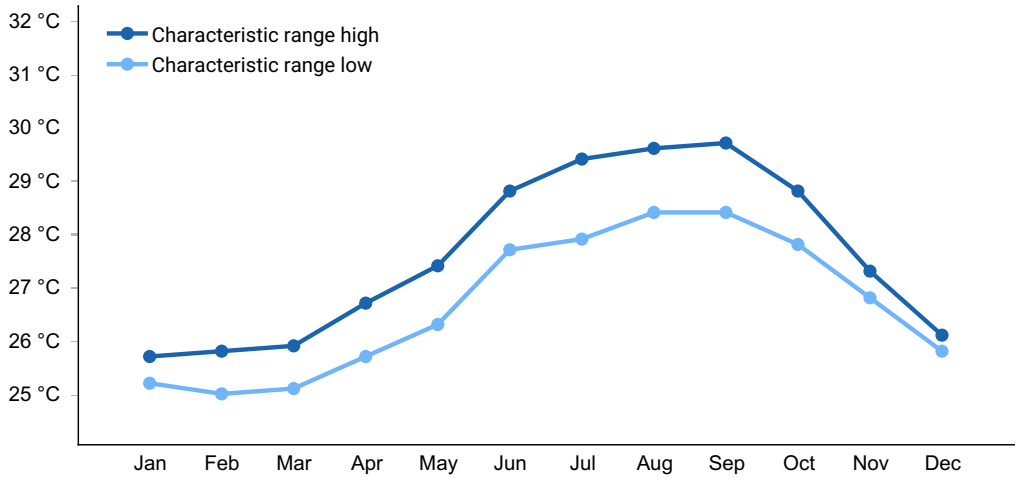

Figure 3. Monthly maximum temperature range

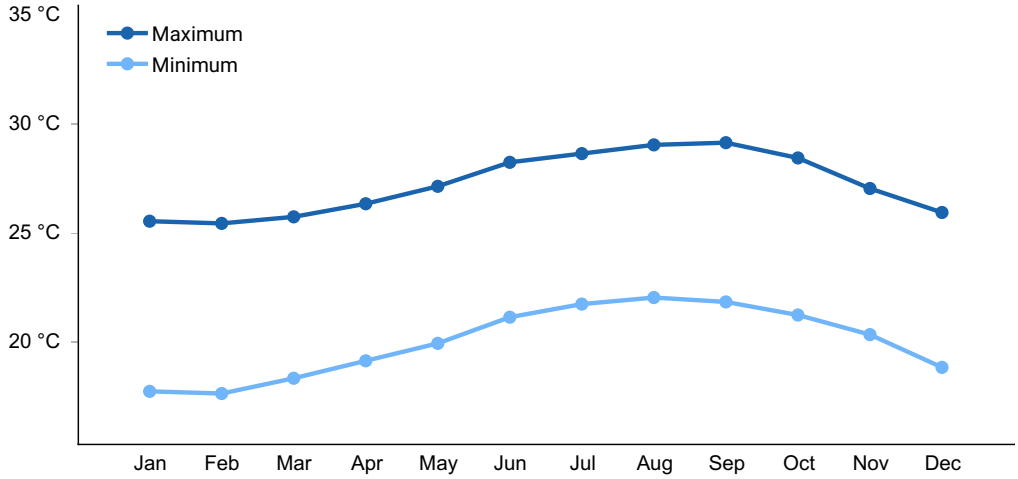

Figure 4. Monthly average minimum and maximum temperature

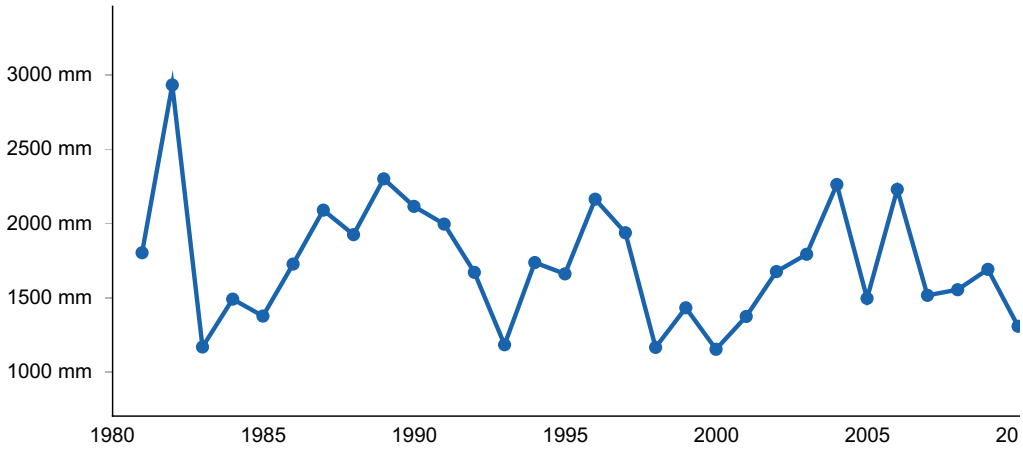

Figure 5. Annual precipitation pattern

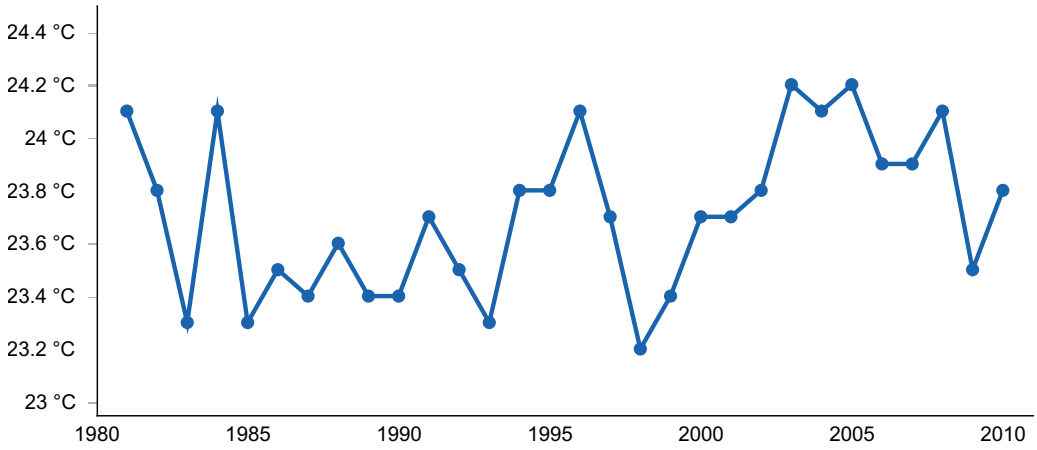

Figure 6. Annual average temperature pattern

Climate stations used

- (1) KANEOHE MAUKA 781 [USC00513113], Kaneohe, HI
- (2) WAIHEE 837.5 [USC00519281], Kaneohe, HI
- (3) PRINCEVILLE RCH 1117 [USC00518165], Princeville, HI
- (4) KILAUEA 1134 [USC00514561], Kilauea, HI
- (5) WAIMANALO EXP F 795.1 [USC00519523], Waimanalo, HI
- (6) MANOA LYON ARBO 785.2 [USC00516128], Honolulu, HI
- (7) WAIMEA VALLEY 892.2 [USC00519603], Haleiwa, HI
- (8) LIHUE WSO AP 1020.1 [USW00022536], Lihue, HI

Influencing water features

This ecological site occurs along perennial streams. According to the National Wetlands Inventory, there are occurrences of wetlands classified as palustrine, fresh water, seasonally to semi permanently flooded forest and scrub/shrub (USFWS, 2023).

Number of National Wetland Inventory (NWI) features overlapping ecological site: Freshwater emergent (839), riverine (368), freshwater forested/shrub (337), freshwater pond (59), estuarine and marine (47), estuarine and marine deepwater (22), and lakes (3) (USFWS, 2023).

Number of National Hydrologic Dataset (NHD) features overlapping ecological site: Lake/pond (46), stream/river (19), reservoir (16), swamp/marsh (16), canal/ditch (1), and sea/ocean (1) (USGS, 2019).

Soil features

The soil components associated with this ecological site are Hanalei, Kolokolo, and Kalihi.

The common features in all the soils of this ecological site are (1) they formed in alluvium in floodplains of perennial streams; and (2) they undergo some degree of flooding at

times. The soil survey specifies the flooding duration is very brief (USDA-SCS, 1972).

Kolokolo soils are in the soil order Inceptisol, which have surface horizons that are high in organic matter and nutrient cations. Kolokolo soils have clay loam surface texture, are very deep, well drained, and have a water table deeper than 72 inches (183 centimeters) from the surface (USDA-SCS, 1972).

Kalihi soils are in the soil order Mollisol, which have surface horizons that are high in organic matter and nutrient cations. Kalihi soils have clay surface texture, are deep, poorly drained, and have a water table that is about 42 inches (107 centimeters) below the soil surface (USDA-SCS, 1972).

Hanalei soils are in the soil order Inceptisols, which have a weakly developed B horizon. They have silty clay surface textures, are moderately deep, somewhat poorly to poorly drained, and have a water table that is typically 42 inches (107 centimeters) from the surface. The map unit Hanalei peaty silty clay loam, 0 to 2 percent slopes, have a peat layer on the surface, and have a water table that is about 6 inches (15 centimeters) from the surface. The map unit Hanalei silty clay, deep water table, 0 to 6 percent slopes has a water table that is 48 inches (122 centimeters) from the surface (USDA-SCS, 1972).

Table 5. Representative soil features

Parent material	(1) Alluvium–igneous rock
Surface texture	(1) Silty clay loam (2) Peaty silty clay loam (3) Stony silty clay (4) Clay (5) Extremely stony clay
Family particle size	(1) Very-fine (2) Fine
Drainage class	Poorly drained to somewhat poorly drained
Permeability class	Very slow to slow
Depth to restrictive layer	183 cm
Soil depth	183 cm
Surface fragment cover <=3"	0%
Surface fragment cover >3"	0–9%
Available water capacity (0-101.6cm)	12.7–17.78 cm
Calcium carbonate equivalent (0-101.6cm)	0%
Electrical conductivity (0-101.6cm)	0 mmhos/cm

Sodium adsorption ratio (0-101.6cm)	0–5
Soil reaction (1:1 water) (0-25.4cm)	4.8–7
Subsurface fragment volume <=3" (0-101.6cm)	2–4%
Subsurface fragment volume >3" (0-101.6cm)	2–47%

Table 6. Representative soil features (actual values)

Drainage class	Poorly drained to well drained
Permeability class	Not specified
Depth to restrictive layer	Not specified
Soil depth	Not specified
Surface fragment cover <=3"	Not specified
Surface fragment cover >3"	Not specified
Available water capacity (0-101.6cm)	Not specified
Calcium carbonate equivalent (0-101.6cm)	Not specified
Electrical conductivity (0-101.6cm)	Not specified
Sodium adsorption ratio (0-101.6cm)	Not specified
Soil reaction (1:1 water) (0-25.4cm)	Not specified
Subsurface fragment volume <=3" (0-101.6cm)	Not specified
Subsurface fragment volume >3" (0-101.6cm)	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 important natural disturbance in this ecological site is flooding of the perennial streams over their banks (USDA-SCS, 1972). The effects of flooding vary according to location and severity of flooding but include destruction of vegetation and deposition of fresh alluvium layers.

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.

Humans arrived in the Hawaiian Islands 1,200 to 1,500 years ago. Their population gradually increased so that by 1,600 A.D. at least 80 percent of all the lands in Hawaii below about 1,500 feet (457meters) in elevation had been extensively altered by humans (Kirch, 1982); some pollen core data suggest that up to 100 percent 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 extensive 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).

Approximately 67 percent (9,238 acres) of this 13,831-acre ecological site overlaps with the Lincoln et al., (2023) modeled Flooded Pondfields agroecological systems. Lincoln et al., (2023, p. 04) states that "Pondfields, known as loʻi in Hawaiʻi, were the preferred agricultural features wherever suitable areas of flat land within river valleys or open floodplains were accessible by the gravitational flow of water. Lincoln et al., (2023, p. 04) also states "Loʻi systems were dominated by the cultivation of kalo (taro; *Colocasia esculenta*), the only Polynesian crop introduced to Hawaiʻi able to withstand flooded conditions, although other crops were cultivated along the terrace banks and the surrounding areas".

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 (Henke, 1929).

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 disturbance in the ecological site is foraging and trampling by domestic and feral ungulates. Excessive foraging can reduce vegetation cover and root abundance, leading to excessive soil erosion and increased stream water temperatures. Trampling compacts soils and can break down stream banks, leading to excessive soil erosion.

State and transition model

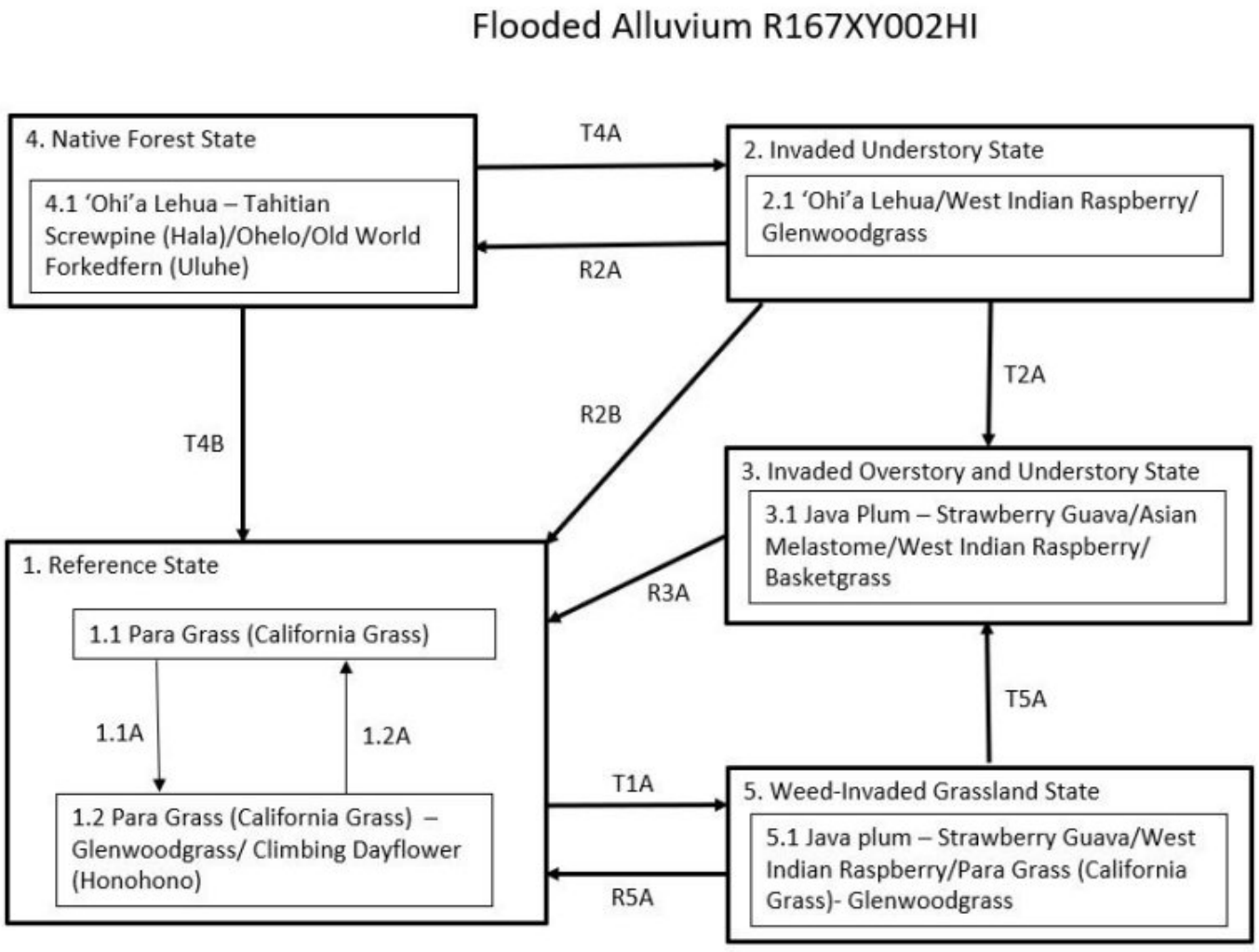

Figure 7. State-and-transition model diagram for Flooded Alluvium (R167XY002HI)

State 1
Reference State

The Reference State (1) consists of two community phases dominated by introduced grass species. This state is considered to be the Reference State because no intact examples of native forest remain, and the species compositions of the forests consisting of introduced species are extremely variable. Continuous grazing results in increased abundance of less desirable forage species, as represented by the phase change from 1.1 Para Grass (California grass) to 1.2 Para Grass - Glenwoodgrass/Climbing Dayflower (Honohono). Longer-term overgrazing and lack of weed control measures results in a transition to the Weed-Invaded Grassland State (5).

Community 1.1
Para Grass (California Grass)

There typically is sparse or no overstory in this community. The dominant forage species is para grass or California grass (*Urochloa mutica*). Better-drained areas may support guineagrass (*Urochloa maxima*). Dominance of desired forage species is maintained by prescribed grazing techniques that allow desired species time to recover from grazing and trampling but includes periods of grazing of sufficient intensity to suppress invasion of weedy shrubs and trees. Failure to properly maintain the selected forage species results in this community phase shifting to community phase 1.2.

Dominant plant species

- para grass (*Urochloa mutica*), grass

Community 1.2
Para Grass (California Grass) – Glenwoodgrass/Climbing Dayflower (Honohono)

This community phase is dominated by grasses and forbs of lower forage value. It can be shifted back to phase 1.1 by applying a prescribed grazing plan. There typically is sparse or no overstory in this community. Para grass or California grass (urochloa mutica) or guineagrass (Urochoa maxima) are still common, but glenwoodgrass (Sacciolepsis indica) and climbing dayflower or honohono (*Commelina diffusa*) have displaced those species to an extent. Common carpetgrass (*Axonopus fissifolius*), hilograss (*Paspalum conjugatum*), rat-tail grass (*Sporobolus indicus* var. capensis), and Meyen's flatsedge (*Cyperus meyenianus*) may also be present in small amounts (Browning et al., 2019; US Army Corps of Engineers, 1981; Wagner et al., 1999). This community phase is dominated by grasses and forbs of lower forage value. It can be shifted back to phase 1.1 by applying a prescribed grazing plan.

Dominant plant species

- para grass (*Urochloa mutica*), grass

- glenwoodgrass (*Sacciolepis indica*), grass
- climbing dayflower (*Commelina diffusa*), other herbaceous

Pathway 1.1A
Community 1.1 to 1.2

Phase 1.1 changes to phase 1.2 by long-term continuous grazing. Remnant high-quality forages have been greatly reduced in abundance and largely replaced by lower-value species. Weedy forbs and shrubs are increasing.

Pathway 1.2A
Community 1.2 to 1.1

Prescribed grazing is needed that provides for intensive but temporary grazing of pastures to ensure that cattle consume some low-value forage species along with preferred forages and to allow preferred forages time to recover from defoliation. Desirable grass species are competitive and able to recover with proper management. The grazing plan may require splitting the herd, creating additional water sources, and creating multiple pastures by cross-fencing. Weed control may be necessary to eliminate some undesirable species.

State 2
Invaded Understory State

The Invaded Understory State (2) consists of one community phase. Native ‘ohi’a lehua and Tahitian screwpine (hala) trees may be present in some locations. However, introduced trees, shrubs, vines, and ferns produce a dense layer of low, competitive vegetation that severely inhibits reproduction of native species. Activity of feral pigs and cattle further reduces native plant abundance and produces bare, disturbed soil patches that promote weed invasion. Eventually, this state transitions to the Invaded Overstory and Understory State (3) through growth of introduced tree species.

Community 2.1
'Ohi'a Lehua/West Indian Raspberry/ Glenwoodgrass

While native trees may be present, introduced tree species have invaded the overstory. Smaller, shade-tolerant introduced trees and shrubs gradually produce extremely dense canopies and root systems that exclude other species. Dense stands of introduced ferns form a layer that inhibits reproduction of native species. ‘Ohi’a lehua (*Metrosideros polymorpha*) and Tahitian screwpine or hala (*Pandanus tectorius*) are present; in some areas, sea hibiscus or hau (*Hibiscus tiliaceus*) forms dense stands near the stream; it is unclear whether this species is native or was introduced by humans. Strawberry guava (*Psidium cattleianum*), guava (*Psidium guajava*), Indian walnut or kukui (*Aleurites moluccanus*), and Java plum (*Syzygium javanicum*) are increasingly abundant in the understory, gradually forming extremely dense stands. Shrubs such as West Indian

raspberry (*Rubus rosifolius*), Asian melastome (*Melastoma candidum*) and false meadowbeauty (*Pterolepis glomerata*) are present and increasing in abundance. Glenwoodgrass (*Sacciolepis indica*) is one of the dominant grass species. Basketgrass (*Oplismenus hirtellus*) thrives under dense, shady canopies (Browning et al., 2019; US Army Corps of Engineers, 1981; Wagner et al., 1999).

Dominant plant species

- 'ohi'a lehua (*Metrosideros polymorpha*), tree
- West Indian raspberry (*Rubus rosifolius*), shrub
- glenwoodgrass (*Sacciolepis indica*), grass

State 3
Invaded Over and Understory State

The Invaded Over and Understory State (3) consists of one community phase dominated by introduced species in both the overstory and understory. Some individual native trees may persist for their lifetime. The diversity of weedy trees, shrubs, vines, ferns, and herbs is high, and the species mix is variable. Conversion to the Reference State (1) is possible by using heavy machinery and applying aggressive weed control and ungulate-exclusion measures.

Community 3.1
Java Plum – Strawberry Guava/Asian Melastome/West Indian Raspberry/Basketgrass

‘Ohi’a lehua (*Metrosideros polymorpha*) and Tahitian screwpine or hala (*Pandanus tectorius*) trees persist until they die, but do not successfully reproduce. The introduced species present on different sites varies. Monotypic or mixed stands of strawberry guava (*Psidium cattleianum*), Indian walnut or kukui (*Aleurites moluccanus*), and Java plum (*Syzygium javanicum*) may develop. The understory varies among locations. Dense overstories may allow only a sparse understory of basketgrass (Oplismensus hirtellus) to grow. A variable mix of shrub, grass, sedge, forb, and vine species is present where more light penetrates the overstory. While native trees may be present, introduced tree species have invaded the overstory. Smaller, shade-tolerant introduced trees and shrubs gradually produce extremely dense canopies and root systems that exclude other species. Dense stands of introduced ferns form a layer that inhibits reproduction of native species. ‘Ohi’a lehua (*Metrosideros polymorpha*) and Tahitian screwpine or hala (*Pandanus tectorius*) are present; in some areas, sea hibiscus or hau (*Hibiscus tiliaceus*) forms dense stands near the stream; it is unclear whether this species is native or was introduced by humans. Strawberry guava (*Psidium cattleianum*), guava (*Psidium guajava*), Indian walnut or kukui (*Aleurites moluccanus*), and Java plum (*Syzygium javanicum*) are increasingly abundant in the understory, gradually forming extremely dense stands. Shrubs such as West Indian raspberry (*Rubus rosifolius*), Asian melastome (*Melastoma candidum*), and false meadowbeauty (*Pterolepis glomerata*) are present and increasing in abundance.

Basketgrass (*Oplismenus hirtellus*) thrives under dense, shady canopies (Browning et al., 2019; US Army Corps of Engineers, 1981; Wagner et al., 1999).

Dominant plant species

- Java plum (*Syzygium javanicum*), tree
- strawberry guava (*Psidium cattleianum*), tree
- Asian melastome (*Melastoma candidum*), shrub
- West Indian raspberry (*Rubus rosifolius*), shrub
- basketgrass (*Oplismenus hirtellus*), grass

State 4
Native Forest State

The Native Forest State (4) consists of one community phase. Because no examples of this state remain, the following description is historical, based on literature and historical accounts of the islands before human influences disturbed these native plant communities. When cleared by machinery or long-term, heavy ungulate browsing, this state transitions to the Reference State (1). Gradual invasion by weedy, introduced plant species brings a transition to the Invaded Understory State (2).

Community 4.1
'Ohi'a Lehua – Tahitian Screwpine (Hala)/Ohelo/Old World Forkedfern (Uluhe)

This historical community phase is a forest with a medium to tall stature (50 to 75 feet or 15 to 23 meters) with closed to open overstory and an understory of small trees, shrubs, vines, and ferns that can survive flooding. The dominant overstory species would have been ‘ohi’a lehua (*Metrosideros polymorpha*) with Tahitian screwpine or hala (*Pandanus tectorius*); in places, sea hibiscus or hau (*Hibiscus tiliaceus*) forms dense stands (Browning et al., 2019; US Army Corps of Engineers, 1981; Wagner et al., 1999). The understory likely would have included Waimea pipturus or mamaki (*Pipturus albidus*) trees. Manfern or hapu’u or tree ferns (Cibotium spp.) would have been present, as would shrubs of the genera Cyanea, Euphorbia, Styphelia, Scaevola, and Vaccinium. Old World forkedfern or uluhe (*Dicranopteris linearis*) and scrambling fern (*Diplopterygium pinnatum*) would have been common as these species thrive in disturbed locations (Browning et al., 2019; US Army Corps of Engineers, 1981; Wagner et al., 1999).

Dominant plant species

- 'ohi'a lehua (*Metrosideros polymorpha*), tree
- Tahitian screwpine (*Pandanus tectorius*), tree
- ohelo (*Vaccinium dentatum*), shrub
- Old World forkedfern (*Dicranopteris linearis*), other herbaceous

State 5
Weed Invaded Grassland State

The Weed Invaded Grassland State (5) consists of one community phase consisting primarily of weedy shrubs and small trees. Weedy grasses and forbs dominate between shrub patches. Introduced tree species are present and will attain dominance if fire does not set them back.

Community 5.1
Java Plum – Strawberry Guava/West Indian Raspberry/ Paragrass (California Grass) - Glenwoodgrass

This community phase has a wide diversity of mostly introduced species. There typically is no or sparse tall overstory. Small strawberry guava (*Psidium cattleianum*), guava (*Psidium guajava*), and Java plum (*Syzygium javanicum*) trees are common. Introduced shrubs, vines, and forbs are common. West Indian raspberry (*Rubus rosifolius*) is a common introduced shrub. Paragrass or California grass (*Urochloa mutica*) is the dominant high quality forage grass. High quality forage grasses are sparse, while low quality species such as marsh bristlegrass (*Setaria parviflora*), hilograss (*Paspalum conjugatum*), glenwoodgrass (*Sacciolepis indica*), and common carpetgrass (*Axonopus fissifolius*) are abundant (Browning et al., 2019; US Army Corps of Engineers, 1981; Wagner et al., 1999).

Dominant plant species

- Java plum (*Syzygium javanicum*), tree
- strawberry guava (*Psidium cattleianum*), tree
- West Indian raspberry (*Rubus rosifolius*), shrub
- glenwoodgrass (*Sacciolepis indica*), grass
- para grass (*Urochloa mutica*), grass

Transition T1A
State 1 to 5

The Reference State (1) transitions to the Weed Invaded Grassland State (5) by long-term continuous grazing and lack of weed control measures. Remnant desirable forages have been grazed out and replaced entirely by weedy grasses, forbs, shrubs, and small trees.

Restoration pathway R2B
State 2 to 1

The Invaded Understory State (2) can be restored to the Reference State (1) by clearing the forest with heavy machinery and planting desirable forage species.

Transition T2A
State 2 to 3

The Invaded Understory State (2) transitions to the Invaded Over and Understory State (3) through the process of fast-growing weeds inhibiting reproduction of native plants and gradually replacing them. This process is accelerated by feral pigs and cattle directly damaging native plants and promoting the spread of weeds by disturbing the soil and spreading weed seeds.

Restoration pathway R2A
State 2 to 4

The Invaded Understory State (2) may be restored to a facsimile of the Native Forest State (4). Construction of a suitable fence and removal of all ungulates are necessary. Intensive weed control must then be initiated and maintained in the long term. In some cases, large amounts of dead weed biomass must be dealt with by removal or decomposition. Reintroduction of missing native species will be necessary.

Restoration pathway R3A
State 3 to 1

The Invaded Over and Understory State (3) can be converted to the Reference State (1) by clearing vegetation using heavy machinery, applying aggressive weed control measures, and planting desirable forage species.

Transition T4B
State 4 to 1

The Native Forest State (4) can transition to the Reference State (1) by clearing the forest with heavy machinery and planting desirable pasture species. Native forest may be cleared gradually by allowing cattle access to the forest. Cattle eventually eat or destroy understory ferns, forbs, shrubs, and saplings, opening the forest so that introduced grasses will thrive.

Transition T4A
State 4 to 2

The Native Forest State (4) transitions to the Invaded Understory State (2) by the very aggressive, introduced weed species present in this ecological site invading intact native forest and gradually replacing native species in the understory. This invasion is greatly facilitated by domestic and feral pigs and cattle that damage and consume native plants, disturb the soil, and spread weed seeds.

Restoration pathway R5A

State 5 to 1

The Weed Invaded Grassland State (5) can be restored to the Reference State (1) by brush management, re-establishment of desirable forage species, persistent weed control, and prescribed grazing.

Transition T5A
State 5 to 3

The Weed Invaded Grassland State (5) transitions to the Invaded Over and Understory State (3) due to the presence of fast-growing, introduced tree species.

Additional community tables

Other references

REFERENCES for R167XY002HI Flooded Alluvium

Athens, J.S. (1997). Prehistoric environmental and landscape change. In Kirch, P.V. & T.L. Hunt (Eds.), Hawai'ian native lowland vegetation in the Pacific Islands (Pgs. 248 - 270). Yale University Press. [https://www.pelagicos.net/BIOL3010/readings/Athens_1997.pdf].

Browning J.H., Reeves M., Amidon F., S. Miller, & Charrier J.C. (2019). Hawai'i: The Wetland System of Hawai'i. Elsevier Inc.

Cuddihy, L.W., & C.P. Stone. (1990). Alteration of native Hawai'ian vegetation: Effects of humans, their activities and introductions. University of Hawaii Cooperative National Park Resources Study Unit.

Department of Land and Natural Resources (2024). Hawai'i State Aha Moku. [https://dlnr.hawaii.gov/ahamoku/councils/].

Giambelluca, T.W., Q. Chen, A.G. Frazier, J.P. Price, Y.L. Chen, P.-S. Chu, J.K. Eischeid, & D.M. Delparte. (2013): Online rainfall atlas of Hawai'i. Bull. Amer. Meteor. Soc. 94, 313-316, DOI: [https://doi.org/10.1175/BAMS-D-11-00228.1].

Giambelluca, T.W., X. Shuai, M.L. Barnes, R.J. Alliss, R.J. Longman, T. Miura, Q. Chen, A.G. Frazier, R.G. Mudd, L. Cuo, & A.D. Businger. (2014). Evapotranspiration of Hawai'i. Final report submitted to the U.S. Army Corps of Engineers - Honolulu District, and the Commission on Water Resource Management, State of Hawai'i. [https://www.hawaii.edu/climate-data-portal/evapotranspiration-atlas/].

Handy, E.S.C., E.G. Handy, & Pukui, M.K. (First Edition 1972, Revised Edition 1991). Native planters in old Hawai'i: Their life, lore, and environment. Bishop Museum Press.

Henke, L.A. (1929). A survey of livestock in Hawai'i. Research Publication No. 5. University of Hawai'i, Honolulu. [https://www.ctahr.hawaii.edu/oc/freepubs/pdf/RP-5.pdf].

Juvik, J.O., & Nullett, D. (1993). A climate transect through tropical montane rain forests in Hawai'i. Department of Geography, University of Hawai'i at Hilo, Hilo Hawai'i. Journal of Applied Meteorology. Volume 33.

Kirch, P.V. (1982). The impact of the prehistoric Polynesians in the Hawai'ian ecosystem. Pacific Science 36 (1):1-14.

Kirch, P.V. (1983). Introduction. In Archaeological investigations of the Mudlane-Waimea-Kawaihae Road Corridor, Island of Hawai'i: An Interdisciplinary Study of an Environmental Transect. Clark, J.T. and Kirch, P.V., eds. Dept. of Anthropology, Bernice Pauahi Bishop Museum, Report 83-1, Honolulu, HI.

Leopold, L.B. (1949). The interaction of trade wind and sea breeze, Hawai'i. Journal of Meteorology 6: 312-320.

Lincoln, N.K, T.P. Haensel, & Lee, T.M. (2023). Modeling Hawai'ian agroecology: Depicting traditional adaptation to the world's most diverse environment. Frontiers in Sustainable Food Systems. Climate-Smart Food Systems. Volume 7 – 2023. [https://doi.org/10.3389/fsufs.2023.1116929].

Malo, D. (1903). Hawaiian antiquities. N.B. Emerson (trans.). Bishop Museum Special Publication 2. Honolulu.

Sanderson, M. (ed.). (1993). Prevailing trade winds, weather and climate in Hawai'i. University of Hawai'i Press. Honolulu.

U.S. Army Corps of Engineers, Honolulu District. (1981). A Guide to Pacific Wetland Plants. L. Stemmermann, ed. Wetland plants for Hawai'i and US-affiliated Pacific islands.

U.S. Department of Agriculture, Natural Resources Conservation Service. (2006). Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. United States Department of Agriculture, Agriculture Handbook 296. [https://www.nrcs.usda.gov/sites/default/files/2022-10/AgHandbook296_text_low-res.pdf].

U.S. Department of Agriculture, Soil Survey Conservation Service. (1972). Soil survey of Islands of Kauai, Oahu, Maui, Molokai, and Lanai, State of Hawai'i. Foote D.E., Hill E.L., Nakamura S., & F. Stephens, in cooperation with The University of Hawai'i Agricultural Experiment Station.

U. S. Department of Interior, Fish & Wildlife Service. (2023). Download seamless wetlands data by state. National Wetlands Inventory website. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. Accessed April 24, 2024.

[https://www.fws.gov/program/national-wetlands-inventory/download-state-wetlands-data].

U.S. Department of Interior, Geological Survey. (2006). A Gap analysis of Hawai'i: February 2006 final report. National gap analysis program. [https://catalog.lib.uchicago.edu/vufind/Record/6329681/Details].

U.S. Department of Interior, Geological Survey. (2019). National Hydrography Dataset (NHD) – USGS national map downloadable data collection: USGS – National Geospatial Technical Operations Center (NGTOC). [https://www.usgs.gov/national-hydrography/access-national-hydrography-products].

Wagner, W.L., D.R. Herbst, & S.H. Sohmer. (1999). Manual of the flowering plants of Hawai'i, Revised Edition. Bishop Museum Press, Honolulu.

Western Regional Climate Center, (2020). Climate of Hawai'i. Available: [https://wrcc.dri.edu/Climate/narrative_hi.php].

DEFINITIONS

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

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

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, 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.

Endosaturation: The soil is saturated with water in all layers from the upper boundary of saturation to a depth of 200 cm or more from the mineral soil surface.

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.

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.

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.

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.

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 1,500 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.

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	04/12/2026
Approved by	Kendra Moseley
Approval date	
Composition (Indicators 10 and 12) based on	Annual Production

Indicators

1. **Number and extent of rills:**

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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:

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

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

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

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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:**

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17. **Perennial plant reproductive capability:**
