Ecological site VX166X01X002
Isothermic Ustic Naturalized Grassland

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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): 166X–Very Stony Land and Rock Land

This MLRA occurs in the State of Hawaii on the islands of Maui, Kahoolawe, Lanai, Molokai, Oahu, Kauai, and Niihau. Elevation ranges from sea level to 8,000 feet (0 to 2,440 meters). The terrain encompasses stony complex slopes and rocky gulches (USDA-NRCS, 2006). The geology is extrusive basic igneous rock (primarily basalt) that are weathered in some areas. Some interfluves are mantled with weathered volcanic ash. Average annual precipitation ranges from 17 to 39 inches (430 to 990 millimeters) (Giambelluca et al., 2013). Extreme average annual precipitation ranges from 10 to 107 inches (254 to 2,720 millimeters). Most of the rainfall occurs from November through March, much of it during kona storms. Average annual air temperatures ranges from 70 to 75 degrees F (21 to 24 degrees C) with little seasonal variation (Giambelluca et al., 2014). Extreme annual air temperatures range from 48 to 82 degrees F (9 to 28 degrees C). Dominant soils are Mollisols, Aridisols, and Entisols with an isohyperthermic, isothermic, or isomesic soil temperature regimes and ustic or aridic soil moisture regimes (USDA-NRCS, 2006). Vegetation consists of forbs, grasses, and shrubs with some trees. Most of the plant species typically encountered are introduced species that have become naturalized in Hawaii. However, areas within this MLRA are critical habitat for rare, threatened, or endangered plant species.

Classification relationships

This ecological site occurs within Major Land Resource Area (MLRA) 166 - Very Stony Land and Rock Land.

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:

Molokai Moku Acres: Kona (556).

Lanai Moku Acres: Lahaina (10,525).

Ecological site concept

This ecological site is largely naturalized grassland at low to middle elevations primarily on Lanai and a small area on the eastern shore of Molokai (USDI-USGS, 2006). Most of the area has been disturbed by ranching, feral animals, and human-caused fires. Principal landowners are large private land companies and a ranch. It is accessible on Lanai along Kanepuu Highway northwest of Lanai City and Route 450 at the eastern end of Molokai.

The central concept of the Isothermic Ustic Naturalized Grassland Ecological Site is of well drained, deep, non-rocky soils in the Mollisols soil order that formed in in alluvium from basic igneous rock (USDA-SCS, 1972). Annual air temperatures and rainfall are associated with warm (isothermic), seasonally dry (ustic) soil conditions. Elevations on Lanai range from about 800 to 2,000 feet (244 to 610 meters) with extremes up to 2,900 feet (884 meters) while elevations on Molokai range from sea level (0 meters) to about 600 feet (183 meters). Because very little of the original native vegetation remains, the Reference State of this ecological site consists of the dominant naturalized grassland vegetation. The dominant grass species are dallisgrass (*Paspalum dilatatum*) and rose Natal grass (*Melinis repens*). Common naturalized trees are white leadtree or koa haole (*Leucaena leucocephala*) and Brazilian peppertree or christmasberry (*Schinus terebinthifolius*).

The original native vegetation was dry forest (Egler, 1947; Wagner et al., 1999). Common species, based on the current environment and remnant occurrences, were lama (*Diospyros sandwicensis*), devil's pepper or hao (*Rauvolfia sandwicensis*), alahe'e (*Psydrax odorata*), koaoha or koaia (*Acacia koa*ia), Florida hopbush or aalii (*Dodonaea viscosa*), Hawai'i hawthorn or ulei (*Osteomeles anthyllidifolia*), queen coralbead or huehue (*Cocculus orbiculatus*), and native grasses.

Associated sites

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 Lanai. It generally has higher annual rainfall than this ecological site, but the two ecological sites are very similar, especially where they adjoin each other at the 158 and 166 MLRA boundary. Being in different MLRAs is the reason these ecological sites are differentiated.
VX165X01X001	**Isothermic Ustic Naturalized Grassland** The Isothermic Ustic Naturalized Grassland Ecological Site (R165XY001HI) adjoins this ecological site on Molokai. It differs from this ecological site by having annual rainfall amounts that overlap but in places exceed those of this ecological site and by having more weathered soils with lower pH and base saturation. R165XY001HI also differs by having soils which are Ultisols, Andisols, and Oxisols rather than Mollisols.

Similar sites

VX161A01X009	**Isothermic Ustic Naturalized Grassland** The Isothermic Ustic Naturalized Grassland Ecological Site (R161AY009HI) occurs only on the island of Hawaii. It is more broadly defined than this ecological site, occurring over a wider range of rainfall and elevations. The two ecological sites overlap in species occurrences and production.
VX161B01X500	**Ustic Isothermic Forest** The Ustic Isothermic Forest Ecological Site (F161BY500HI) occurs on the island of Hawaii. It is correlated with young Andisols that are formed in volcanic ash or organic matter on slightly weathered aa or pahoehoe rather than the older, weathered, non-rocky Mollisols in alluvium of this ecological site. Plant species are similar in both sites.
VX160X01X007	**Isothermic Ustic Naturalized Grassland (Kikuyugrass)** The Isothermic Ustic Naturalized Grassland Ecological Site (R160XY007HI) occurs on Maui. Although it shares soil temperature and moisture regimes with this ecological site, it ranges largely into higher elevations with higher annual rainfall. At its lower, drier elevations it has similar native dry forest and introduced species to this ecological site, but most of it has different species and more diverse native species.

Table 1. Dominant plant species

Tree	Not specified
Shrub	Not specified
Herbaceous	(1) *Paspalum dilatatum* (2) *Melinis repens*

Legacy ID

R166XY002HI

Physiographic features

This ecological site occurs on alluvial fans on shield volcanoes (USDA-SCS, 1972). The water table is deeper than 72 inches (183 centimeters).

Table 2. Representative physiographic features

Landforms	(1) Shield volcano > Alluvial fan (2)
Runoff class	Medium to high
Flooding frequency	None to rare
Ponding frequency	None
Elevation	305–610 m
Slope	3–25%
Water table depth	183 cm
Aspect	N, E, SE, SW

Table 3. Representative physiographic features (actual ranges)

Runoff class	Not specified
Flooding frequency	Not specified
Ponding frequency	Not specified
Elevation	0–884 m
Slope	Not specified
Water table depth	Not specified

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 23 to 27 inches (58 to 69 centimeters) while actual (10th and 90th percentiles) values range from 22 to 30 inches (56 to 76 centimeters). Extreme values range from 19 to 56 inches (48 to 142 centimeters). The mean annual precipitation is 26 inches (66 centimeters), and the median annual average precipitation is also 25 inches (64 centimeters). Located in the rain shadow of Maui, Lanai is relatively dry. A large portion of

the water in the island's aquifer comes from fog drip pulled from clouds by trees and ferns in upper elevations.

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 70 to 73 degrees F (21 to 23 degrees C) while actual (10th and 90th percentiles) values also range from 68 to 73 degrees F (20 to 23 degrees C). Extreme values range from 66 to 81 degrees F (19 to 27 degrees C). The mean annual temperature is 72 degrees F (22 degrees C) and the median annual temperature is also 72 degrees F (22 degrees C).

Rainfall occurs as occasional light trade wind showers that drift over from the windward side of the island 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. The central area of Lanai is exposed to strong trade winds (Sanderson, 1993; USDA-SCS, 1972).

No suitable Western Region Climate Stations occur in or near this ecological site (WRCC, 2020). The data in the climate normals tables below are from the University of Hawaii.

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. Molokai, Oahu, and Lanai, 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. 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 (USDA-SCS, 1972; Western Regional Climate Center, 2020).

Besides the trade winds discussed above, other rainfall sources on the Hawaiian Islands include: a) "Naulu storms" (Leopold, 1949) 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).

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 (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)	584-686 mm
Frost-free period (actual range)	365 days
Freeze-free period (actual range)	365 days
Precipitation total (actual range)	559-762 mm
Frost-free period (average)	365 days
Freeze-free period (average)	365 days
Precipitation total (average)	660 mm

Influencing water features

The area is dissected by numerous intermittent streams (USFWS, 2023).

Number of National Wetland Inventory (NWI) features overlapping ecological site: Riverine (48), freshwater emergent wetland (3), estuarine and marine wetland (2), and estuarine and marine deepwater (1) (USFSW, 2023).

Number of National Hydrologic Dataset (NHD) features overlapping ecological site: Sea/ocean (1) (USGS, 2019).

Soil features

The soil components associated with this ecological site are Kanepuu and Koele.

These are in the Mollisols soil order (USDA-SCS, 1972). Many of the soils in warm (isothermic), seasonally dry (ustic) areas of Hawaii are Mollisols or have mollic properties. Their key properties 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. The original native vegetation here was probably dry forest.

The soils have an isothermic (warm) soil temperature regime and an ustic soil moisture regime (in normal years, dry for more than 90 cumulative days but less than 180 days). All the soils are very deep (at least 60 inches or 152 centimeters), well drained, not rocky, and have silty clay or silty clay loam textures. When measured during this soil survey in the late 1960s, surface pH was as low as 4.5 in surface horizons where pineapple was cultivated. This phenomenon has been studied in locations around the world and is due to factors involved in pineapple cultivation. The Soil Survey of Islands of Kaui, Oahu, Maui, Molokai, and Lanai, state of Hawaii for the Koele series that "...soil is slightly acid to medium acid, except that the surface layer is generally very strongly acid in areas used for pineapple" (USDA-SCS, 1972, p. 70). It is possible that surface pH has reverted to normal in the decades since pineapple cultivation ended. If planning to establish crops, forage, or trees on these soils or in areas that had been cultivated for pineapple, a pH test is advisable (USDA-SCS, 1972).

Table 5. Representative soil features

Parent material	(1) Alluvium–igneous rock
Surface texture	(1) Silty clay (2) Silty clay loam
Family particle size	(1) Fine
Drainage class	Well drained
Permeability class	Moderately slow to moderate
Depth to restrictive layer	183 cm
Soil depth	183 cm
Surface fragment cover <=3"	12%
Surface fragment cover >3"	0%

Available water capacity (0-101.6cm)	12.7–15.24 cm
Calcium carbonate equivalent (0-101.6cm)	0%
Electrical conductivity (0-101.6cm)	0–2 mmhos/cm
Sodium adsorption ratio (0-101.6cm)	0
Soil reaction (1:1 water) (0-25.4cm)	4.5–6.7
Subsurface fragment volume <=3" (0-101.6cm)	80%
Subsurface fragment volume >3" (0-101.6cm)	0%

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

There have been no lava flows or heavy volcanic ash flows on this ecological site that are recent enough to have affected the current vegetation and soils (USDA-SCS, 1972). It is possible that strong storms may sometimes cause windthrow of trees. Wildfires started by lightning are very rare (Abrahamson, 2013).

HUMAN DISTURBANCES

Human-related disturbances have been more important than natural disturbances in this ecological site since the arrival of Polynesians and, later, Europeans. This is 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 (roughly 457 meters) 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 large areas under intensive agriculture. However, much of this ecological site was probably too dry for agriculture, except possibly burning to favor the growth of tanglehead or pili grass (*Heteropogon contortus*) used for thatching. This would have greatly reduced tree and shrub cover to create patches of pili grassland (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, animals, possibly plant diseases, and wood harvesting. The introduced Pacific rat would have eaten bird eggs, invertebrates, and the seeds of native plants (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. Introduced kiawe (*Prosopis pallida*) and white leadtree or koa haole (*Leucaena leucocephala*) trees are widespread in this ecological site.

The Polynesians introduced dogs, Pacific rats, and small pigs to the islands. After European discovery, 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. Additionally, packs of feral dogs had become established, as confirmed by reports of their depredations on sheep. By 1851, records reported severe overstocking of pastures, lack of fences, and large numbers of feral livestock (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 (including deer), birds, reptiles, amphibians, invertebrates, plants, and microorganisms, have brought about dramatic changes to wild ecosystems in Hawaii. Most of the original forest of this ecological site was cleared and converted to intensive, irrigated production of sugarcane and pineapple, and the remaining native plant communities have been highly disturbed. Much of the area had been under cultivation, was later abandoned, and then converted to grazing land or urban uses.

Since the loss of the native dry forests and abandonment of modern agriculture, most of this ecological site has been utilized by livestock or is farmed (USDI-USGS, 2006).

The most severe human-connected disturbance, in the past and still occurring, is accelerated soil erosion from wind and water where vegetation has been impacted by overuse by domestic and feral ungulates and fires started by humans.

State and transition model

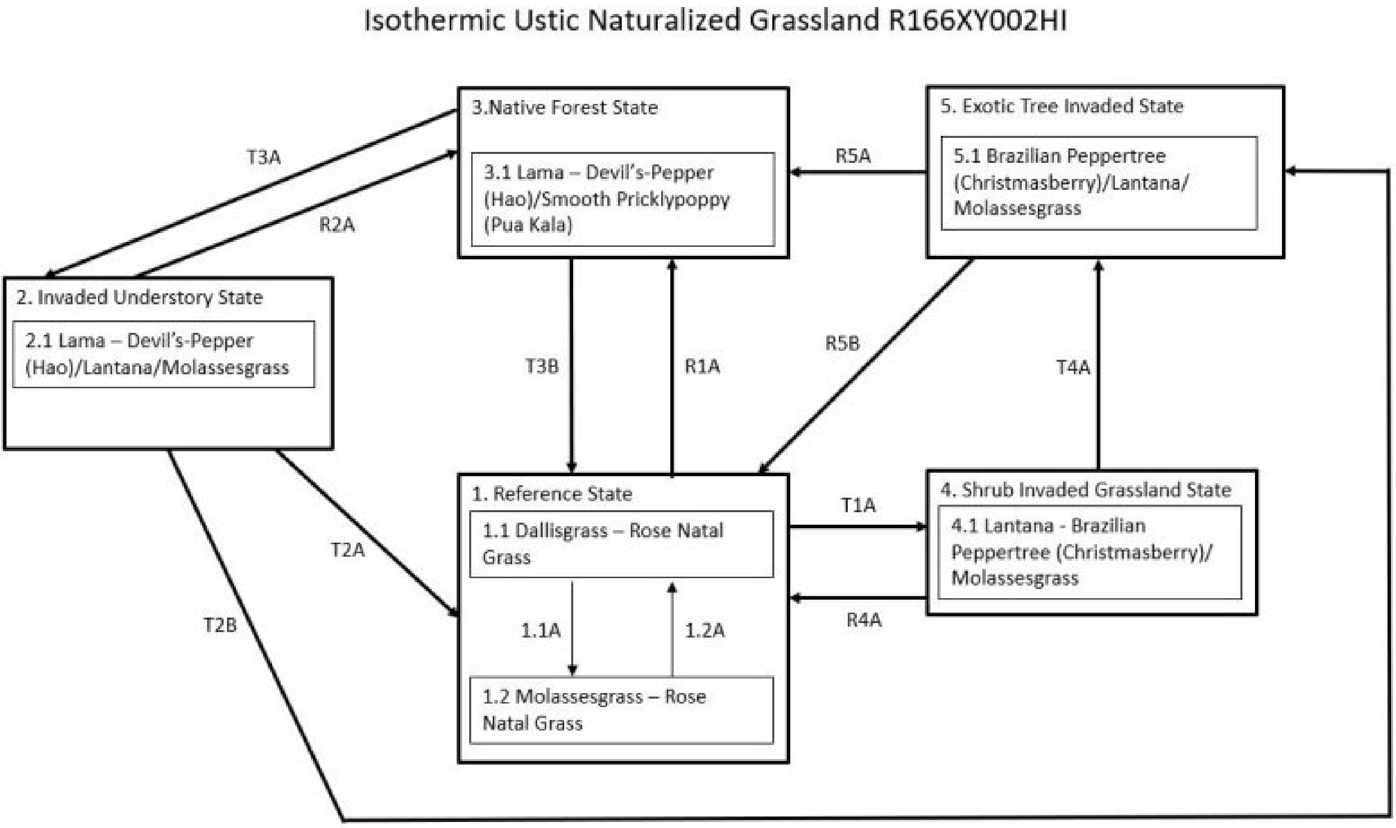

Figure 1. State-and-transition model diagram for the Isothermic Ustic Naturalized Grassland Ecological Site (R166XY002HI).

State 1
Reference State

The Reference State (1) consists of two community phases. It is naturalized grassland with introduced grasses, forbs, and scattered shrubs and trees. With continuous heavy grazing, preferred forage grasses decrease. Less preferred grass, forb, and shrub species increase under such circumstances. With severe deterioration, shrubby species can increase to eventually dominate, causing a transition to the Shrub Invaded Grassland State (4).

Community 1.1
Dallisgrass – Rose Natal Grass

Dallisgrass (*Paspalum dilatatum*) and rose Natal grass (*Melinis repens*) are the dominant forage grass species; guineagrass (*Urochloa maxima*) may be common in some areas. Some white leadtree or koa haole (*Leucaena leucocephala*) may be present (Egler, 1947; Wagner, 1999).

Dominant plant species

- dallisgrass (*Paspalum dilatatum*), grass
- rose Natal grass (*Melinis repens*), grass

Community 1.2
Molassesgrass – Rose Natal Grass

Molassesgrass (*Melinis minutiflora*) is an increaser species that will dominate this community under heavy grazing. Rose Natal grass (*Melinis repens*) is still present but not dominant in cover or biomass.

Dominant plant species

- molassesgrass (*Melinis minutiflora*), grass
- rose Natal grass (*Melinis repens*), grass

Pathway 1.1A
Community 1.1 to 1.2

Community phase 1.1 converts to phase 1.2 by frequent fire that reduces competitiveness of the dominant grasses and allows invasion of weeds, particularly undesirable grasses. Continuous grazing without adequate rest for preferred forages will have the same result. This conversion by either factor can be avoided if timely application of deferred, prescribed grazing, or both are carried out to allow recovery of desirable species before weeds become dominant.

Pathway 1.2A
Community 1.2 to 1.1

Community phase 1.2 can be converted to phase 1.1 by removing undesirable species and favoring and reestablishing desirable forage species. Prescribed grazing will eventually bring about the conversion.

State 2
Invaded Understory State

The Invaded Understory State (2) consists of one community phase having an open canopy of common native trees with an understory of introduced grasses, ferns, vines, small trees, and shrubs. Foraging by feral or domestic ungulates removes native understory plants and prevents regeneration of overstory species, resulting in a mature and diminishing canopy of native trees. This may occur more gradually by weed invasion into intact native forest. The understory of this plant community contains fine fuels that are susceptible to fire.

Community 2.1
Lama – Devil's-Pepper (Hao)/Lantana/Molassesgrass

Native tree species dominate the overstory. The understory consists of a variable array of introduced plant species along with remnant native species. The overstory is dominated by lama (*Diospyros sandwicensis*), devil's-pepper or hao (*Rauvolfia sandwicensis*), and other typical dry forest species. Tree species diversity varies from widely among locations and between islands; please consult the accompanying native species list. Among native shrubs, Florida hopbush or aalii (*Dodonaea viscosa*) and pukiawe (*Styphelia tameiameiae*) may still be present. The introduced shrub lantana (*Lantana camara*) can be very abundant, producing stands that make foot transit difficult. The introduced vine corkystem passionflower or huehue haole (*Passiflora suberosa*) can become very abundant, covering the canopies of remnant native understory plants. Introduced grasses are abundant where sufficient light penetrates the canopy. Brazilian pepper tree or christmasberry (*Schinus terebinthifolius*), an introduced small tree that produces a dense, shady canopy, may be abundant. Introduced grasses such as molassesgrass (*Melinis minutiflora*) grow where there is adequate sunlight (Egler, 1947; Wagner, 1999). .

Dominant plant species

- lama (*Diospyros sandwicensis*), tree
- devil's-pepper (*Rauvolfia sandwicensis*), tree
- lantana (*Lantana camara*), shrub
- molassesgrass (*Melinis minutiflora*), grass

State 3
Native Forest State

The Native Forest State (3) consists of one community phase. Very little native vegetation remains in this ecological site. The following description is historical, based on literature and historical accounts of the islands before human influences disturbed these native plant communities and on similar ecological sites on the Island of Hawaii. The general appearance of this ecological site is an open to nearly closed canopy up to 40 feet (12 meters) tall, an understory of shrubs and small trees, and a sparse ground layer of vines, forbs, and grasses. The canopy becomes shorter and sparser where the forest grades into drier or windier areas.

Community 3.1
Lama – Devil's-Pepper (Hao)/Smooth Pricklypoppy (Pua Kala)

In this historical community phase, the tree canopy would have been dominated by lama (*Diospyros sandwicensis*), devil's-pepper or hao (*Rauvolfia sandwicensis*), and other typical Hawaiian dry forest species. 'Ohi'a lehua (*Metrosideros polymorpha*), Koaoha or Koaia (*Acacia koa*ia), and Hawai'i olive or olopua (*Nestegis sandwicensis*) would have been common in some areas. Alahe'e (*Psydrax odorata*), a small tree, would have been the most abundant species in the understory. Common shrubs would have been Florida hopbush or aalii (*Dodonaea viscosa*), yellow 'ilima (*Sida fallax*), Hawai'i hawthorn or ulei (*Osteomeles anthyllidifolia*), and alaweo (*Chenopodium oahuense*). Queen coralbead or huehue (*Cocculus orbiculatus*) would have been the most common vine. Native forbs including smooth pricklypoppy or pua kala (*Argemone glauca*), grasses, and ferns would have been present but not abundant (Egler, 1947; Wagner, 1999).

Dominant plant species

- lama (*Diospyros sandwicensis*), tree
- devil's-pepper (*Rauvolfia sandwicensis*), tree
- smooth pricklypoppy (*Argemone glauca*), other herbaceous

State 4
Shrub Invaded Grassland State

The Shrub Invaded Grassland State (4) consists of one community phase. It may have developed on abandoned grazing land, land cleared by fire, or abandoned farmland. Shrubs are dominant in canopy cover and stature. Typically, an array of introduced grass species is present. There is a moderate but increasing cover of small trees, some which potentially can grow to large stature. This tree cover creates the potential for a transition to the Exotic Tree Invaded State (5).

Community 4.1
Lantana - Brazilian Peppertree (Christmasberry)/Molassesgrass

The shrub community usually is dominated by introduced species but can be a mix of native and introduced species. The most common introduced species present are Brazilian peppertree or christmasberry (*Schinus terebinthifolius*), white leadtree or koa haole (*Leucaena leucocephala*), both of which are of small stature in this community phase, and lantana (*Lantana camara*). Guava (*Psidium guajava*) is common in areas with higher rainfall or cooler temperatures. Pukiawe (*Styphelia tameiameiae*), Florida hopbush or aalii (*Dodonaea viscosa*), and yellow ‘ilima (*Sida fallax*) are native shrubs that may be common in some locations. Introduced grasses such as molassesgrass (*Melinis minutiflora*) grow where there is adequate sunlight (Egler, 1947; Wagner, 1999).

Dominant plant species

- lantana (*Lantana camara*), shrub
- Brazilian peppertree (*Schinus terebinthifolius*), shrub
- molassesgrass (*Melinis minutiflora*), grass

State 5
Exotic Tree Invaded State

The Exotic Tree Invaded State (5) is comprised of one community phase dominated by introduced trees. Density and composition of understory shrubs, forbs, and grasses varies greatly with overstory closure and height, which affects the susceptibility of this plant community to fire. The density, vigor, and biomass of introduced vegetation can be very high, making restoration to other states expensive and difficult.

Community 5.1
Christmasberry (Brazilian Peppertree)/Lantana/Molassesgrass

In many cases, the overstory consists of very dense Brazilian peppertree or christmasberry (*Schinus terebinthifolius*) that is 15 to 25 feet (4.6 to 8 meters) tall with very little understory. Introduced tree species such as silkoak (*Grevillea robusta*), Scotch attorney or autograph tree (*Clusia rosea*), Indian walnut or kukui (*Aleurites moluccanus*), and octopus tree (*Schefflera actinophylla*) that have greater height potentials than christmasberry are often able to grow up through the christmasberry canopy and eventually dominate the site. Remnant, mature ‘ohi’a lehua (*Metrosideros polymorpha*) trees may be present but are not able to regenerate. Native alahe’e (*Psydrax odorata*) trees sometimes can reproduce and maintain a sparse population in the understory (Egler, 1947; Wagner, 1999). The overstory composition can be highly variable from site to site, but christmasberry is typically the most abundant species. Christmasberry often dominates any remaining understory (greater than 13 feet or 4 meters tall) and can be so dense as to exclude most other species. Where more light is available, guava (*Psidium guajava*) and white leadtree or koa haole (*Leucaena leucocephala*) are common, and guava may dominate wetter or cooler sites. Lantana (*Lantana camara*) is the most common shrub to be found. Introduced grasses such as molassesgrass (*Melinis minutiflora*) grow where there is adequate sunlight (Egler, 1947; Wagner, 1999).

Dominant plant species

- Brazilian peppertree (*Schinus terebinthifolius*), tree
- lantana (*Lantana camara*), shrub
- molassesgrass (*Melinis minutiflora*), grass

Restoration pathway R1A
State 1 to 3

It may be possible to restore the Reference State (1) to a plant community resembling the Native Forest State (3). Weed control must be applied to forage species and the many opportunistic plant species that would invade the site. Weed control would be a perpetual process to maintain the site. Fire and domestic and feral ungulates must be excluded. Extensive planting of native species would follow. If severe soil erosion has occurred, more intensive restoration measures are needed.

Transition T1A
State 1 to 4

The Reference State (1) transitions to the Shrub Invaded Grassland State (4) after abandonment and, if wildfires do not occur, gradual invasion of weedy shrubs and small trees. If the site contained abundant white leadtree (koa haole) before abandonment, these small trees would overtop the grasses and greatly increase in abundance unless heavily browsed.

Transition T2A
State 2 to 1

The Invaded Understory State (2) transitions to the Reference State (1) by land clearing with heavy machinery or fire followed by weed control. Land clearing would probably promote germination of the weed seed bank in the soil, requiring herbicidal control. After clearing and weed control, the site would be planted to forage species.

Restoration pathway R2A
State 2 to 3

The Invaded Understory State (2) may be restored to the Native Forest State (3) by removal of the introduced understory through intensive weed control. Reintroduction of native understory species is required. The site must be fenced securely to exclude ungulates. If severe soil erosion has occurred, more intensive restoration measures are needed.

Transition T2B
State 2 to 5

The Invaded Understory State (2) transitions to the Exotic Tree Invaded State (5) by growth of introduced tree species through and above the native canopy. Lack of reproduction leads to gradual loss of most native tree species.

Transition T3B
State 3 to 1

The Native Forest State (3) transitions to the Reference State (1) by clearing the forest and planting desirable forage species.

Transition T3A
State 3 to 2

The Native Forest State (3) transitions to the Invaded Understory State (2) through grazing, browsing, rooting, and trampling by domestic or feral ungulates (cattle, sheep, deer, goats, and pigs). These activities destroy small native plant species and seedlings and saplings of large species. Regeneration of the native forest is prevented, leading to tree populations consisting almost entirely of mature plants. Lack of competition from native plants, introduction of weed seeds, and disturbance of the soil lead to an understory dominated by introduced plant species. Weeds can invade intact native forest even in the absence of ungulates and gradually bring about the transition. Invasive vines, shrubs, and small trees will grow under intact native canopies and begin to degrade the forest. Eventually, introduced grasses provide fine fuels that can carry fires that destroy the native tree canopy.

Restoration pathway R4A
State 4 to 1

The Shrub Invaded Grassland State (4) can be restored to the Reference State (1) by brush management with follow-up control of resprouting shrubs and emerging weedy forbs. Forage species may then be replanted and maintained by prescribed grazing. If severe soil erosion has occurred, more intensive restoration measures are needed.

Transition T4A
State 4 to 5

The Shrub Invaded Grassland State (4) transitions to the Exotic Tree Invaded State (5) with lack of fire. Fast-growing introduced tree species invade Shrub Invaded Grassland and quickly overtop shrubs.

Restoration pathway R5B
State 5 to 1

The Exotic Tree Invaded State (5) may be restored the Reference State (1). Total clearing of the site would be necessary. If clearing is done by heavy machinery, soil disturbance would occur. This would probably induce germination of the weed seed bank and increase the potential for soil erosion. Weed control and brush management must then be applied multiple times to control new weed germination and resprouting. After clearing and weed control, the site would be planted to forage species. Ungulates must be excluded until forages are well established; prescribed grazing must then be applied.

Restoration pathway R5A
State 5 to 3

It may be possible to restore the Tree Invaded State (5) to a community resembling the Native Forest State (3). Total clearing of the site would be necessary. Alternatively, it may be worthwhile to kill taller weed species in place to provide some shelter from the sun. If clearing is done by heavy machinery, soil disturbance would occur. This could induce germination of the weed seed bank and increase the potential for soil erosion. Weed control and brush management would be long-term. Fire and ungulates must be excluded. If severe soil erosion has occurred, more intensive restoration measures are needed.

Additional community tables

Other references

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DEFINITIONS

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

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, wili wili, and buffelgrass. The terms aridic and torric are basically the same.

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.

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.

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.

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.

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:**

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:**
