USDA Natural Resources
Conservation Service

Ecological site VX163X01X003
East Aspect Isohyperthermic 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): 163X–Alluvial Fans and Coastal Plains

This MLRA is in the State of Hawaii on the islands of Maui, Lanai, Molokai, Oahu, and Kauai. Elevation ranges from sea level to 800 feet (0 to 244 meters) with elevation extremes up to 1,600 feet (488 meters). The terrain is nearly level and gently sloping coastal plains and adjacent alluvial fans. Beneath the unconsolidated sediments are basalt, coral limestone, calcareous sand deposits, volcanic ash, coral sand, and fill. Average annual precipitation ranges from 10 to 40 inches (254 to 1,016 millimeters) with precipitation extremes up to 122 inches (3,099 millimeters) in select places on Oahu and Kauai (Giambelluca et al., 2013). Most of the rainfall occurs from November through March during kona storms that come in from the leeward side of the islands. Average annual temperatures range from 68 to 82 degrees F (20 to 28 degrees C) with little seasonal variation (Giambelluca et al., 2014). Dominant soils are Mollisols, Aridisols, Entisols, and Vertisols with an isohyperthermic soil temperature regime and aquic or aridic (torric) to ustic soil moisture regimes. Vegetation consists of forbs, grasses, and shrubs with some trees. Almost all the plant species typically encountered are introduced species that have become naturalized in Hawaii.

Classification relationships

This ecological site occurs within Major Land Resource Area (MLRA) 163 - Alluvial Fans and Coastal Plains.

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:

Maui Moku Acres: Pu’ali Komohana (5,500), Hamakuapoko (501), Kula (12), and Hamakualoa (7).

Ecological site concept

This ecological site is largely naturalized grassland at low elevations on the eastern slope of the West Maui Mountains. Scattered outliers occur on the lower slopes of Haleakala below the towns of Pukalani and Makawao. Much of the area is, or has been, in intensive agriculture or has been developed (USDI-USGS, 2006). Principal landowners are large private land companies, ranches, and the State of Hawaii. It is accessible along Routes 30 and 330 from Waihee to Waikapu.

The central concept of the East Aspect Isohyperthermic Naturalized Grassland is of well drained, very deep soils with mollic (high organic matter and base saturation) properties that formed in alluvium from basic igneous rock. Annual air temperatures and rainfall are associated with very warm (isohyperthermic), seasonally dry (ustic) soil conditions (USDA-SCS, 1972). The east-facing aspect shields the site from the sun during the hottest parts of the day. Elevations range from sea level (0 meters) to about 1,000 feet (305 meters) with extremes up to 1,500 feet (457 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 is guineagrass (*Urochloa maxima*). 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 (Rock, 1913; Wagner et al., 1999). Common species, based on the current environment and remnant occurrences, were lama (*Diospyros sandwicensis*), alahe’e (*Psydrax odorata*), ohe makai (*Reynoldsia sandwicensis*), wili wili (*Erythrina sandwicensis*), naio (Myoporum sandwicense), koaohe or koaia (Acacia koaia), Florida hopbush or aalii (*Dodonaea viscosa*), Hawai’i hawthorn or ulei (*Osteomeles anthyllidifolia*), queen coralbead or huehue (*Cocculus orbiculatus*), and native grasses.

Associated sites

VX158X01X002	**Isohyperthermic Torric Naturalized Grassland Kiawe/buffelgrass (Prosopis pallida/Pennisetum ciliare)** The Isohyperthermic Torric Naturalized Grassland Ecological Site has a warmer and drier climate than this ecological site and does not have the protection of an east-facing aspect, making it even warmer and drier. It supports plant species adapted to a drier environment.
VX163X01X002	**Sandy Shrubland** The Sandy Shrubland Ecological Site has a warmer and drier climate than this ecological site and does not have the protection of an east-facing aspect, making it even warmer and drier. It also has sandy soils with much less water-holding capacity than this ecological site and supports plant species adapted to a much drier environment.

Similar sites

VX163X01X004	**South and West Aspect Isohyperthermic Naturalized Grassland** The South and West Aspect Isohyperthermic Naturalized Grassland has a similar climate to this ecological site but does not have the protection of an east-facing aspect, making it warmer and drier. It supports plant species adapted to a drier environment.

Table 1. Dominant plant species

Tree	(1) *Leucaena leucocephala*
Shrub	Not specified
Herbaceous	(1) *Urochloa maxima*

Legacy ID

R163XY003HI

Physiographic features

This ecological site occurs on alluvial fans on the sloping mountainsides of shield volcanoes (USDA-SCS, 1972).

Table 2. Representative physiographic features

Landforms	(1) Shield volcano > Alluvial fan (2) Shield volcano > Mountain slope
Runoff class	Low to medium
Flooding frequency	None

Ponding frequency	None
Elevation	0–305 m
Slope	0–15%
Water table depth	183 cm
Aspect	E

Table 3. Representative physiographic features (actual ranges)

Runoff class	Not specified
Flooding frequency	Not specified
Ponding frequency	Not specified
Elevation	0–457 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 25 to 37 inches (635 to 940 millimeters) while actual (10th and 90th percentiles) values for annual average precipitation range from 23 to 41 inches (584 to 1,041 millimeters). Extreme values range from 19 to 59 inches (483 to 1,499 millimeters). The mean annual precipitation is 31 inches (787 millimeters) and the median annual average precipitation is 30 inches (762 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 75 to 77 degrees F (24 to 25 degrees C) while actual (10th and 90th percentiles) values for annual temperatures range from 73 to 81 degrees F (23 to 27 degrees C). Extreme values range from 70 to 82 degrees F (21 to 28 degrees C). The mean annual temperature is 77 degrees F (25 degrees C) and the median annual temperature is 75 degrees F (24 degrees C).

There is not a good spread of representative climate stations to choose from for this ecological site. The Kahului Airport site is too hot, too dry, and too low to be a representative standalone climate station (Western Regional Climate Center, 2020). The climate data populated in the 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).

The islands lie within the trade wind zone. Significant amounts of moisture are picked up from the ocean by trade winds up to an altitude of more than about 6,000 feet (1,850 meters). As the trade winds from the northeast are forced up the mountains of the islands their moisture condenses, creating rain on the windward slopes; the leeward sides of the island receive little of this moisture (USDA-SCS, 1972; Western Regional Climate Center, 2020).

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).

On the windward sides of the island, cool, moist air at higher elevations descends toward the ocean where it meets the trade winds; this process brings rainfall, often at night, to lower elevation areas (USDA-SCS, 1972).

Extensive low-pressure systems often approach the islands from the west, producing heavy rainstorms that primarily affect the leeward sides, but can envelope the entire island. These major storms occur most frequently between October and March (USDA-SCS, 1972).

Sea-to-land naulu winds regularly flow up the western and southern slopes of Haleakala on Maui, forming clouds on these faces of the mountain between about 3,000 to 6,000 feet (925 to 1,850 meters). These clouds form a shadow at lower elevations and produce fog drip at higher elevations where the clouds contact the mountain (Leopold 1949; Schroeder 1981).

Table 4. Representative climatic features

Frost-free period (characteristic range)	365 days
Freeze-free period (characteristic range)	365 days

Precipitation total (characteristic range)	635-940 mm
Frost-free period (actual range)	365 days
Freeze-free period (actual range)	365 days
Precipitation total (actual range)	584-1,041 mm
Frost-free period (average)	365 days
Freeze-free period (average)	365 days
Precipitation total (average)	787 mm

Influencing water features

This ecological site is dissected by numerous intermittent streams, and a few perennial streams (Iao, Waihee, and Waiehu Rivers). It is overlapped by various wetland types which are listed below (USFWS, 2023).

Number of National Wetland Inventory (NWI) Features overlapping Ecological Site: riverine (73), freshwater pond (16), freshwater emergent wetland (7), and freshwater forested/shrub wetland (6) (USFWS, 2023).

Number of National Hydrologic Dataset (NHD) Features overlapping Ecological Site: lake/pond (24), and swamp/marsh (1) (USGS, 2019).

Soil features

The soil components associated with this ecological site are Iao and Wailuku.

These soils are in the Mollisols soil order. They are well drained and very deep (deeper than 60 inches or 150 centimeters). Most of the soils formed in place in alluvium derived from basic igneous rock. Surface horizons from 0 to 10 inches (0 to 254 millimeters) have pH values ranging from 6.1 to 7.0 while pH values from 10 to 20 inches (254 to 508 millimeters) range from 6.1 to 7.1. Surface textures are silty clay or clay (USDA-SCS, 1972).

The key properties of Mollisols are a combination of a relatively thick, dark surface horizon (mollic epipedon) that does not become hard when dry, a dominance of calcium among the extractable cations, and a dominance of crystalline clay minerals of moderate or high cation-exchange capacity. These properties are conducive to plant growth. Although Mollisols usually form under grass in seasonally dry climates, they can form under a forest ecosystem. The original native vegetation here was dry forest (USDA-SCS, 1972).

Table 5. Representative soil features

Parent material	(1) Alluvium–igneous rock (2) Alluvium–basalt
Surface texture	(1) Clay (2) Silty clay (3) Cobbly silty clay
Family particle size	(1) Fine
Drainage class	Well drained
Permeability class	Slow to very slow
Depth to restrictive layer	183 cm
Soil depth	183 cm
Surface fragment cover <=3"	0%
Surface fragment cover >3"	0–13%
Available water capacity (0-101.6cm)	12.7–15.24 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)	6.1–7
Subsurface fragment volume <=3" (0-101.6cm)	2–11%
Subsurface fragment volume >3" (0-101.6cm)	1–21%

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 minor windthrow of trees. Fires started by lightning rarely affect this ecological site (Western Regional Climate Center, 2020).

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 475 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 (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).

Approximately 70 percent (4,842 acres) of this 6,932-acre ecological site overlaps with the Lincoln et al., (2023) modeled Rainfed agroecological systems; Of which, 40 percent (2,793 acres) are modeled as Intensive Rainfed systems, and 30 percent (2,049 acres) are modeled as Marginal Rainfed systems.

The Intensive Rainfed agroecological types which were constructed across broad areas on fertile soils in higher rainfall areas which were known as the zones of planting. Lincoln et al., (2023 p. 04) states that these "systems are sometimes referred to as fixed-field systems due to the dominant agricultural infrastructure of kuaiwi–long, linear embankments of earth and/or stone that served both agronomic and social functions (Allen, 2001; Lincoln and Vitousek, 2017; Lincoln et al., 2017)". These Intensive Rainfed cultivation systems would often include taro or kalo (Alocasia spp.), banana or maia (Musa spp.), tiplant or kı (*Cordyline fruticosa*), sugarcane or ko (*Saccharum officinarum*), kava or awa (*Piper methysticum*), batflower, arrowroot, or pia (*Tacca leontopetaloides*), and bitter ginger, shampoo ginger, or awapuhi (*Zingiber zerumbet*). (Lincoln et al., 2023).

The Marginal Rainfed agroecological types were constructed in on areas subject to marginal rainfall. These systems primarily consisted of drought resistant species such as the sweepotato or uala (*Ipomoea batatas*), or bottle gourd or ipu (*Lagenaria siceraria*) (Lincoln et al., 2023).

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. 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. Much 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.

State and transition model

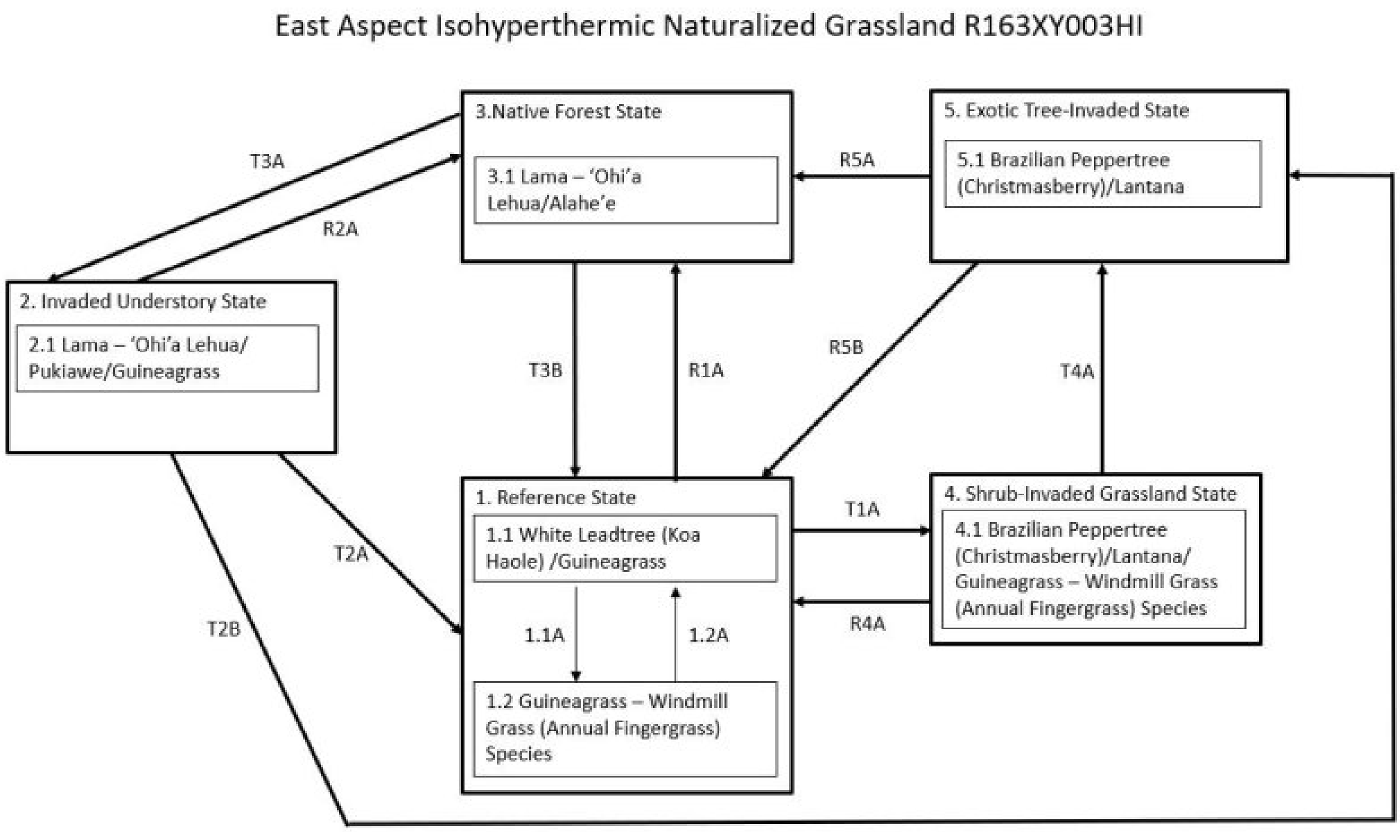

Figure 1. State-and-transition model diagram for the East Aspect Isohyperthermic Naturalized Grassland (R163XY003HI).

State 1
Reference State

The Reference State (1) consists of two community phases. It is naturalized grassland with introduced grasses, forbs, and trees. Scattered large trees are sometimes present.

Community 1.1
White Leadtree (Koa Haole)/Guineagrass

Figure 2. Reference State (1). Phase 1.1. White leadtree (koa haole)/guineagrass. Iao clay, 3 to 7 percent. Elevation ~ 50 feet. Precipitation Zone ~ 30 inches. Taken in Waihee, Hawaii on the island of Maui. John Proctor. 11/14/23.

This community phase consists of introduced grasslands dominated by guineagrass (*Urochloa maxima*). Preferred forage species are guineagrass, the leguminous vine perennial soybean or glycine (*Neonotonia wightii*), and white leadtree or koa haole, a small leguminous tree. Brazilian peppertree or christmasberry (*Schinus terebinthifolius*) is present but not abundant. With continuous heavy grazing, particularly by cattle, preferred forage grasses decrease, as will preferred small trees, vines, and shrubs. Less preferred grass, forb, and shrub species increase under such circumstances. With severe deterioration, shrubby species can increase to eventually dominate.

Dominant plant species

- white leadtree (*Leucaena leucocephala*), tree
- guineagrass (*Urochloa maxima*), grass

Community 1.2
Guineagrass – Windmill Grass (Annual Fingergrass) Species

Shrub-sized Brazilian peppertree or christmasberry (*Schinus terebinthifolius*) has become more abundant. Guineagrass is still the most abundant grass species but is less dominant. Primary increaser grass species that increase under heavy grazing include rose Natal grass or Natal redtop (*Melinis repens*), barbwire grass (*Cymbopogon refractus*), feather fingergrass (*Chloris virgata*), Indian goosegrass or wiregrass (*Eleusine indica*), rat-tail grass (*Sporobolus indicus* var. capensis), crabgrass (Digitaria spp.), Bermudagrass (*Cynodon dactylon*), Colombian bluestem (*Schizachyrium condensatum*), and broomsedge bluestem (*Andropogon virginicus*). Unpalatable increaser forbs include sensitive partridge pea (*Chamaecrista nictitans*), shameplant or sensitive plant (*Mimosa pudica*), smooth rattlebox or rattlepod (*Crotalaria pallida*), lilac tasselflower or red pualele (*Emilia sonchifolia*), and spiny amaranth (*Amaranthus spinosus*). Shrubby species include lantana (*Lantana camara*), American black nightshade or apple of Sodom (*Solanum americanum*), threelobe false mallow (*Malvastrum coromandelianum*), Sacramento burbark (*Triumfetta semitriloba*), balloon plant (*Asclepias physocarpa*), hairy Indian mallow (*Abutilon grandifolium*), and castorbean (*Ricinus communis*).

Dominant plant species

- guineagrass (*Urochloa maxima*), grass
- windmill grass (*Chloris*), grass

Pathway 1.1A
Community 1.1 to 1.2

Community phase 1.1 converts to phase 1.2 by continuous grazing without adequate rest for preferred forages. This conversion can be avoided by timely application of deferred or prescribed grazing to control guineagrass stature and allow recovery of desirable species after grazing or browsing.

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 establishing desirable pasture species. Because guineagrass is still fairly abundant, prescribed grazing may eventually affect the conversion. Pitted beardgrass (*Bothriochloa pertusa*) and rose Natal grass (*Melinis repens*) have some value as forage. However, annual fingergrasses, barbwire grass, Colombian bluestem, broomsedge bluestem are unpalatable to livestock and difficult to control by grazing. If pasture condition is very poor, active weed control measures followed by reestablishment of guineagrass will be necessary.

State 2
Invaded Understory State

The Invaded Understory State (2) consists of one community phase having an open or closed 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, particularly guineagrass, that are susceptible to intense fires.

Community 2.1
Lama – ‘Ohi’a Lehua/Pukiawe/Guineagrass

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, 'ohi'a lehua, and other typical native dry forest species such as wili wili (*Erythrina sandwicensis*) and 'ohe makai (*Reynoldsia sandwicensis*) at lower elevations and cheesewood or hoawa (Pittosporum spp.) and Hawai’i olive or olopua (*Nestegis sandwicensis*) at higher elevations (Rock, 1913; Wagner et al., 1999). 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. The introduced vine corkystem passionflower or huehue haole (*Passiflora suberosa*) can become very abundant, covering the canopies of remnant, low-stature native understory plants. Guineagrass is abundant beneath the overstory canopy, which generally is not adequately dense to reduce its growth. Brazilian peppertree or christmasberry (*Schinus terebinthifolius*), an introduced small tree that produces a dense, shady canopy, may be abundant.

Dominant plant species

- lama (*Diospyros sandwicensis*), tree
- 'ohi'a lehua (*Metrosideros polymorpha*), tree
- guineagrass (*Urochloa maxima*), grass

State 3
Native Forest State

The Native Forest State (3) consists of one community phase. This description is historical, because very little native vegetation remains in this ecological site. The following description is based on literature and historical accounts of the islands before human influences disturbed these native plant communities as well as similar ecological sites. The general appearance of this ecological site is an open to nearly closed canopy up to 40 feet (12 meters) tall when dominated by lama (*Diospyros sandwicensis*) or to 70 feet (22 meters) when dominated by ohia lehua, an understory of shrubs and small trees, and a ground layer of vines, forbs, and grasses. The canopy becomes shorter and sparser where the forest grades into drier areas near the coast.

Community 3.1
Lama – ‘Ohi’a Lehua/Alahe’e

The tree canopy is dominated by lama (*Diospyros sandwicensis*) and ‘ohi’a lehua (*Metrosideros polymorpha*). Alahe’e (*Psydrax odorata*), a small tree or shrub, is the most abundant species in the understory. Common shrubs are Florida hopbush or aalii

(*Dodonaea viscosa*), yellow ‘ilima (*Sida fallax*), Hawai’i hawthorn or ulei (*Osteomeles anthyllidifolia*), and false ohelo or akia (Wikstroemia spp.). Queen coralbead or huehue (*Cocculus orbiculatus*) is the most common vine. Native forbs, grasses, and ferns are present but not abundant (Rock, 1913; Wagner et al., 1999).

Dominant plant species

- lama (*Diospyros sandwicensis*), tree
- 'ohi'a lehua (*Metrosideros polymorpha*), tree
- alahe'e (*Psydrax odorata*), shrub

State 4
Shrub Invaded Grassland State

The Shrub Invaded Grassland State (4) consists of one community phase. It may have developed from abandoned grazing land, land cleared by wildfire, 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
Brazilian Peppertree (Christmasberry)/Lantana/Guineagrass – Windmill Grass (Annual Fingergrass) Species

This community is dominated by small trees, shrubs, and grasses. The most common introduced trees present are Brazilian peppertree or christmasberry (*Schinus terebinthifolius*) and, if it has not been eliminated by excessive browsing, white leadtree or koa haole (*Leucaena leucocephala*). Lantana (*Lantana camara*) is the most common shrub. If still heavily grazed, windmill grass or annual fingergrasses are most common; otherwise, guineagrass is dominant between shrubs and beneath koa haole.

Dominant plant species

- Brazilian peppertree (*Schinus terebinthifolius*), tree
- lantana (*Lantana camara*), shrub
- guineagrass (*Urochloa maxima*), grass
- windmill grass (*Chloris*), 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
Brazilian Peppertree (Christmasberry)/Lantana

In many cases, the overstory consists of very dense Brazilian peppertree or christmasberry that is 15 to 25 feet (4.5 to 7.6 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 may overtop 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. The overstory composition can be highly variable from site to site, but christmasberry is often the most abundant species. Christmasberry often dominates the understory (less than 13 feet or 4 meters tall) and can be so dense as to exclude most other species. Where more light is available, the small, introduced trees common guava (*Psidium guajava*) and white leadtree or koa haole (*Leucaena leucocephala*) are common. Lantana (*Lantana camara*) is the most common shrub.

Dominant plant species

- Brazilian peppertree (*Schinus terebinthifolius*), tree
- lantana (*Lantana camara*), shrub

Restoration pathway R1A
State 1 to 3

It is 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 must be excluded. Domestic and feral ungulates must be excluded by a suitably designed and maintained fence. Extensive planting of native species would follow.

Transition T1A
State 1 to 4

The Reference State (1) transitions to the Shrub Invaded Grassland State (4) through further overgrazing or abandonment. Fire will temporarily prevent this transition. White leadtree (koa haole) will be greatly reduced by over browsing. If the site contained abundant koa haole and was then abandoned, these small trees overtop guineagrass and greatly increase in abundance. Otherwise, there is gradual invasion by weedy shrubs and small trees.

Transition T2A
State 2 to 1

The Invaded Understory State (2) transitions to the Reference State (1) by land clearing with heavy machinery followed by weed control. Land clearing can promote germination of the weed seed bank in the soil, requiring intensive weed 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), or to a facsimile of the Reference State, by removal of the introduced understory through weed control. Reintroduction of native understory species is required. The site must be fenced securely to exclude ungulates.

Transition T2B
State 2 to 5

The Invaded Understory State (2) transitions 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 plants.

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 (cows, 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 intense 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.

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 overtop shrubs, or Brazilian peppertree (christmasberry) increases in stature and density to become dominant.

Restoration pathway R5B
State 5 to 1

The Exotic Tree-Invaded State (5) may be restored to 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 Exotic Tree-Invaded State (5) to a community resembling the Native Fores State (3). Total clearing of the site would be necessary. Alternatively, it may be worthwhile to kill taller weed species in place by herbicide applications in order to provide some shelter for the ground. If clearing is done by heavy machinery, soil disturbance would occur. This could induce germination of the weed seed bank and also increase the potential for soil erosion. Weed control would be ongoing. Protection from fire is needed, and ungulates must be excluded by a suitable fence.

Additional community tables

Other references

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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.

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

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

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.

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.

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

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.

Residuum: Unconsolidated mineral material that has chemically and physically weathered from rock and has not moved from its place of origin.

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.

Torric soil moisture regime: See Aridic soil moisture regime.

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

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	03/31/2026
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:**
