USDA Natural Resources
Conservation Service

Ecological site VX164X01X002
Organic Surface Forest

Last updated: 5/08/2025
Accessed: 04/08/2026

General information

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

MLRA notes

Major Land Resource Area (MLRA): 164X–Humid and Very Humid Steep and Very Steep Mountain Slopes

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

Classification relationships

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

Ecological site concept

This ecological site consists of a moist forest type on the windward slope of Haleakala on the Island of Maui. It lies mostly within the Koolau Forest Reserve between 1000 and 4500 feet (308 and 1385 meters) in an area mauka of Hana Highway (Rte. 360), southeast of Makawao, and northwest of Hana and Kipahulu. Few public roads provide access to this ecological site, and foot access is difficult. Some areas are accessible from Olinda and Hana Highway.

The central concept of the Organic Surface Forest is of well drained, deep soils formed in deposits of volcanic ash deposited over lava flows. The soils have an organic horizon (O horizon) about three inches (7.5 centimeters) thick on the surface. Annual air temperatures and rainfall are associated with warm (isothermic), moist (udic) soil conditions. These soils support forest with an overstory of ohia lehua (*Metrosideros polymorpha*) and, in some places, koa (*Acacia koa*), a secondary tree canopy of olapa (*Cheirodendron trigynum*), scattered tree ferns or hapuu (Cibotium spp.), and an understory of shrubs, grasses, sedges, and ferns. Many trees exhibit a gnarled growth form, and there is a thick growth of mosses, liverworts, and small ferns on tree trunks in areas that are frequently shrouded in fog.

Many of the soils adjoining this ecological site have not been mapped in detail due to difficult accessibility. Much of the rain forest that extends to the east of this ecological site, as well as some areas in the West Maui mountains, is on similar soils and has the same or similar vegetation. The accompanying Native Species List suggests species that are likely to occur on this much larger area and not just on the area correlated with Honomanu soil series.

Associated sites

VX164X01X001	**Gleyed Soil Forest** The Gleyed Soil Forest and the Organic Surface Forest co-occur on Maui, although the Gleyed Soil Forest also occurs on Molokai. Both ecological sites share about the same climates and elevations. The Gleyed Soil Forest is poorly drained, rather than well or moderately well drained, and has a thick peat surface horizon rather than a thin O horizon of decaying litter with some mineral soil material. The Gleyed Soil Forest has open canopy, low stature vegetation consisting of wetness-adapted species and stunted rainforest species rather than a medium stature rain forest.
VX159A01X003	**Isohyperthermic Perudic Naturalized Grassland (Guineagrass - Californiagrass)** The Isohyperthermic Perudic Naturalized Grassland abuts the extreme eastern, low elevation boundary of the Organic Surface Forest on Maui. The Isohyperthermic Perudic Naturalized Grassland has similar rainfall but a much warmer climate than the Organic Surface Forest and does not have a consistent O surface horizon. It would have had a rainforest dominated by ohia lehua with pandanus (Tahitian screwpine) and wet forest lama rather than an ohia lehua/koa forest. It occurs on Maui and Hawaii.

VX160X01X007	**Isothermic Ustic Naturalized Grassland (Kikuyugrass)** The Isothermic Ustic Naturalized Grassland borders the Organic Surface Forest's low elevation southwestern boundary on Maui; it also occurs on Hawaii. On Maui, the Isothermic Ustic Naturalized Grassland lies on the leeward side of Haleakala, giving it a much drier, sunnier climate that has well drained, fertile soils that support diverse dry to mesic forest rather than rainforest species.
VX160X01X502	**Isomesic-Cool Isothermic Forest** The Isomesic-Cool Isothermic Forest borders the Organic Surface Forest's high elevation southwestern boundary on Maui; it also occurs on Hawaii. The Isomesic-Cool Isothermic Forest lies on the leeward side of Haleakala, giving it a drier, sunnier, but cool climate that has well drained, more fertile soils that support moderately dry forest dominated by koa and mamane trees rather than rainforest species.

Similar sites

VX164X01X500	**Volcanic Ash Forest** The Volcanic Ash Forest occurs on Kohala on Hawaii rather than on Maui. The two ecological sites share similar climates, but the Volcanic Ash Forest has less-acidic soils and lacks a consistent surface organic horizon. The character of the vegetation is similar in the two ecological sites, but koa trees do not occur in the Volcanic Ash forest and some plant genera and species differ due to evolutionary and biogeographical reasons.

Table 1. Dominant plant species

Tree	(1) *Metrosideros polymorpha* (2) *Acacia koa*
Shrub	(1) *Labordia venosa*
Herbaceous	Not specified

Legacy ID

F164XY002HI

Physiographic features

This ecological site occurs on volcanic ash fields deposited over lava flows on sloping mountainsides of shield volcanoes.

Table 2. Representative physiographic features

Landforms	(1) Shield volcano > Mountainside (2) Shield volcano > Ash field > Lava flow unit

Runoff class	Low
Flooding frequency	None
Ponding frequency	None
Elevation	305–1,372 m
Slope	5–25%
Water table depth	152 cm
Aspect	N

Climatic features

Summary for this ecological site
Average annual precipitation ranges from 125 to 225 inches (3125 to 5625 millimeters). Rainfall is well-distributed throughout the year with an enhanced rainy season from October through April. Additional moisture is derived from condensation of fog on vegetation. Mean annual soil temperature ranges from 62 to 70 degrees F (17 to 21 degrees C), although higher elevation areas within this ecological site probably have still lower temperatures. Frost free and freeze free periods are 365 days per year.

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

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

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

The zones of highest rainfall on the flanks of Haleakala, on the eastern portion of Maui, lie at elevations of 2000 to 4000 feet (615 to 1230 meters). In the West Maui mountains, which are lower than 6000 feet (1850 meters), the highest rainfall is along or near the summits. Fluctuating between approximately 5000 and 7000 feet (1540 to 2150 meters) elevation on Haleakala is a temperature inversion at the boundary between moist air and higher, drier air. Distinct vegetation changes occur within a short distance at the inversion layer, with lush forest vegetation below the layer and dry savanna, shrubland, grasslands, and sparsely vegetated areas above it. In winter, major storms may deposit snow on the upper slopes of Haleakala, but snow accumulations on the ground typically do not last long.

Low-elevation (to about 2000 feet or 615 meters) areas on the leeward sides of Maui are very warm, sunny, and dry. The central valley, between Haleakala and West Maui, is very warm and dry; this valley is also windy due to trade winds passing around the northwest corner of Haleakala.

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.

Extensive low-pressure systems often approach Maui 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.

Sea-to-land naulu winds regularly flow up the western and southern slopes of Haleakala, forming clouds on these faces of the mountain between about 3000 to 6000 feet (925 to 1850 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). Fog drip contributes a significant amount of water to vegetation and soil in addition to rainfall, and the proportion of annual moisture provided by fog drip is higher in areas with relatively low rainfall (Juvik and Nullet 1993).

Table 3. Representative climatic features

Frost-free period (characteristic range)	365 days
Freeze-free period (characteristic range)	365 days
Precipitation total (characteristic range)	3,175-5,715 mm
Frost-free period (average)	365 days
Freeze-free period (average)	365 days
Precipitation total (average)	7,315 mm

Influencing water features

Perennial streams are common on this site; they typically flow in steep-walled gulches and canyons. Localized bogs occur on areas with little slope.

Vegetation in small gulches is similar to that of the rest of the ecological site. Vegetation on steep walls of large, deep gulches often harbors rare plant species such as laukahi kuahiwi (Plantago princeps), waiawi (Kadua elatior), and apeape (Gunnera petaloidea).

Soil features

This ecological site is correlated with one soil series, Honomanu. It is classified in the Great Group of Hydrudands, which is in the Andisols soil order. These soils formed in weathered volcanic ash deposited on basic igneous rock. The soil temperature regime is isothermic (warm); the soil moisture regimes is udic (soil moisture control section is not dry in any part for as long as 90 cumulative days in normal years). The soils are hydrous, meaning that they consist of fine minerals derived from volcanic ash that have a very high water content at the crop wilting point. They are well drained and deep. Honomanu soils have a surface organic layer that is about three inches (7.5 centimeters) thick that consists of decaying vegetable matter and some mineral soil. It contains many roots but can be lost when the original vegetation has been removed.

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

Much of the remote forest area to the east of the Honomanu soils and also in small areas of the West Maui Mountains is classified in the 1972 Soil Survey as Hydrandepts. Today, they are classified as Hydrudands. They are described as being similar to Honomanu soils. Hydrandepts or Hydrudands occur on sloping, well drained areas of the Hydrandepts – Tropaquods association (map unit rHT). This large area is likely to contain similar vegetation to that described in this ecological site.

Table 4. Representative soil features

Parent material	(1) Volcanic ash
Surface texture	(1) Silty clay
Family particle size	(1) Hydrous
Drainage class	Well drained
Permeability class	Moderately slow

Depth to restrictive layer	183 cm
Soil depth	183 cm
Surface fragment cover <=3"	0%
Surface fragment cover >3"	0%
Available water capacity (0-101.6cm)	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
Soil reaction (1:1 water) (0-101.6cm)	3.5–5
Subsurface fragment volume <=3" (0-101.6cm)	0–10%
Subsurface fragment volume >3" (0-101.6cm)	0–45%

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

The natural (not human-related) disturbances most important for discussion in this ecological site are lava flows and wind throw. Much of this ecological site has not been affected by local volcanic activity for tens or hundreds of thousands of years. Limited areas may be subject to future lava flows that would bury those areas. Wind throw of vegetation can occur during hurricanes or other high wind events.

Human Disturbances

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

Humans arrived in the Hawaiian Islands 1200 to 1500 years ago. Their population gradually increased so that by 1600 AD at least 80 percent of all the lands in Hawaii below about 1500 feet (roughly 500 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). The lowest parts of this ecological site may have been part of the Hawaiian agricultural field system before the arrival of Europeans. 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. Human access to the higher elevations of this ecological site is very difficult.

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

The Polynesians introduced dogs, Pacific rats, and small pigs to the islands. Cattle, sheep, horses, goats, and larger European pigs were introduced in the final decades of the 18th century. These animals ranged free on the islands, becoming very numerous and destructive by the early decades of the 19th century. 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, 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 the regular occurrence of fires. Much of the original forest area remains. However, the native plant community in many areas has been disturbed and, in some places, destroyed due to clearing and abandonment, establishment of exotic timber trees, domestic and feral ungulate foraging, and invasion by introduced plant species. Introduced plant species are capable of completely and permanently replacing native forest.

Foraging by feral cattle and pigs or forest clearing and abandonment facilitate invasion by weeds. However, introduced weeds appear able to successfully invade native stands regardless of human or ungulate disturbances.

State and transition model

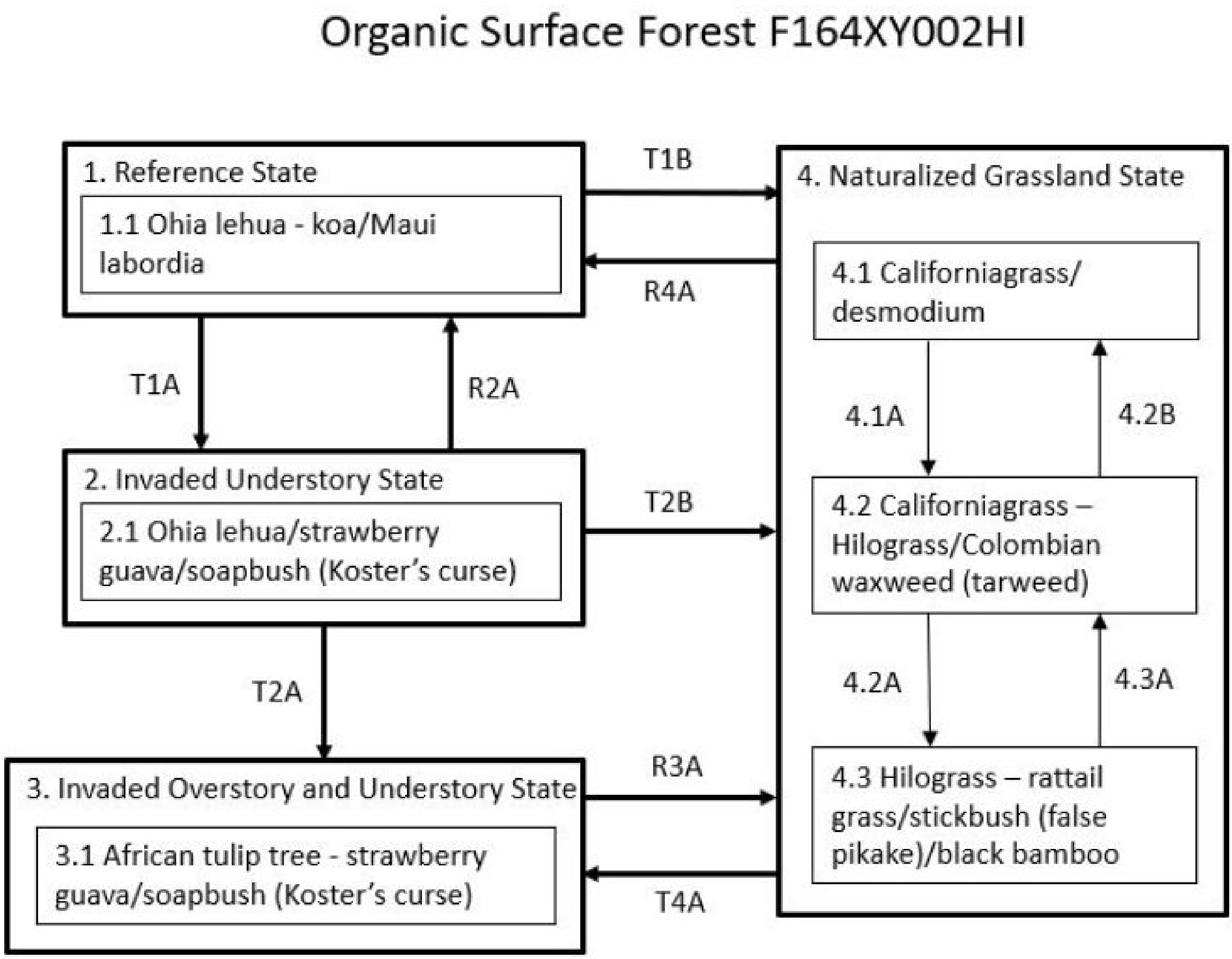

Figure 1. State and Transition Model for the Organic Surface Forest (F164XY002HI)

State 1
Reference State

The Reference State consists of one community phase consisting of medium-stature rainforest. This state transitions into State 2 Invaded Understory by weed invasion; the transition is accelerated by disturbance from domestic and feral ungulates. It transitions to State 4 Naturalized Grassland by mechanical clearing or gradual clearing by uncontrolled grazing and browsing by ungulates, followed by establishment of forage grasses or invasion by weedy introduced grasses.

Community 1.1
Ohia lehua – koa/Maui labordia

There is a gradient of temperature and moisture conditions from the lowest to the highest elevations of this ecological site. Warm, moist conditions prevail at lower elevations; middle elevations are frequently shrouded in clouds and fog; and the very highest elevations are cooler and less wet. Undelineated aquic (water-saturated) soils interrupt this general climate-based pattern and are in the Gleyed Soil Forest (F164XY001HI) ecological site. Throughout the ecological site, the overstory is dominated by ohia lehua.

Olapa (*Cheirodendron trigynum*), kawau (*Ilex anomala*), kolea lau nui (*Myrsine lessertiana*), and manono (Kadua affinis) typically share the canopy with ohia lehua. Koa is often present in the overstory, but is codominant only in a few areas. Overstory height tends to increase from low to high elevation. In the fog-laden middle elevations, many ohia lehua trees branch close to the ground and have a gnarled growth form, and there is usually a heavy growth of mosses, liverworts, and small ferns on tree trunks. Widely-distributed shrub and small tree species include ohelo (*Vaccinium dentatum* and *V. calycinum*), kanawao (*Broussaisia arguta*), kolea lau lii (*Myrsine sandwicensis*) and many species of Clermontia and Cyanea. The native loulu palm species, present in middle elevations, is *Pritchardia arecina*. Three hapuu or tree fern species are present: *Cibotium glaucum* (most common), *C. menziesii* (common), and *C. chamissoi* (uncommon). Widely-distributed vines are hoi kuahiwi (*Smilax melastomifolia*), ieie (*Freycinetia arborea*), akala (*Rubus hawaiensis*), and kilioe (*Embelia pacifica*). Widely-distributed forbs and grass/grasslike species are kaluaha (*Astelia menziesiana*), alaala wai nui (Peperomia spp.), Hawaii sedge (*Carex alligata*), ahuawa (Cyperus hypochlorous), and Hawaii birdcatching sedge (*Uncinia uncinata*). Many small fern species are present, but widely-distributed species are akolea (*Athyrium microphyllum*), ae (*Polypodium pellucidum*), hoio or pohole (*Diplazium sandwichianum*), amau (*Sadleria pallida*), ekaha (*Elaphoglossum crassifolium*), pakahakaha (*Lepisorus thunbergianus*), and piipiilau manamana (*Asplenium lobulatum*).

Dominant plant species

- 'ohi'a lehua (*Metrosideros polymorpha*), tree
- koa (*Acacia koa*), tree
- Maui labordia (*Labordia venosa*), shrub

State 2
Invaded Understory State

This state consists of one community phase. It arises by invasion by introduced species of intact native forest (the Reference State) or, in some cases, of native overstory stands from which the original understory has been cleared. Native species are unable to regenerate in the highly competitive understory of introduced plants and eventually die out. With time, large, introduced tree species will emerge to replace the native overstory trees and form a new overstory. When this last step has occurred, the site will have transitioned to State 3 Invaded Overstory and Understory. Disturbance of the soil and direct damage to native understory plants by introduced ungulates, particularly pigs and cattle, will speed the transition to this state by killing native plants and by creating better germination sites for introduced species. Restoration to the Reference State or a facsimile of it is possible by fencing the site, removing all ungulates, applying weed control measures, and replanting native species when needed. Restoration efforts will be affected depending on the degree of invasion by introduced species and by the species that have invaded the site. Long term weed management and fence maintenance will be necessary.

Community 2.1
Ohia lehua-strawberry guava/soapbush (Koster's curse)

The community has an intact or diminished overstory of native trees with a dense understory of introduced shrubs, ferns, vines, grasses, and small trees. The overstory consists of ohia lehua (*Metrosideros polymorpha*) and sometimes koa (*Acacia koa*). Other native species are somewhat diminished. The only native species remaining in the lower canopy levels are a few native trees and some hapuu (*Cibotium glaucum*) and hapuu li (*Cibotium menziesii*). Small native fern species may be diverse but less abundant than in the Reference state. The understory can contain a diverse mixture of introduced species. Strawberry guava or waiawi (*Psidium cattleianum*) is very common. Other common small tree species are Java plum (*Syzygium cumini*), common guava (*Psidium guajava*), black bamboo (*Phyllostachys nigra*), christmasberry (*Schinus terebinthifolius*), and shoebutton ardisia (*Ardisia elliptica*). Koster's curse or soapbush (*Clidemia hirta*) and cane tibouchina (*Tibouchina herbacea*). Many introduced forb, grasses, sedge, and fern species may occur.

Dominant plant species

- 'ohi'a lehua (*Metrosideros polymorpha*), tree
- strawberry guava (*Psidium cattleianum*), tree
- soapbush (*Clidemia hirta*), shrub

State 3
Invaded Over and Understory State

This state is comprised of one plant community dominated by introduced species in both the overstory and understory. Understory vegetation usually is very sparse to nonexistent. Remnant individuals of a few native species may persist. This state might be considered a dead end as far as further succession. Mechanical clearing followed by establishment of introduced forage species would bring a transition to State 4 Naturalized Grassland.

Community 3.1
African tulip tree – strawberry guava/soapbush (Koster's curse)

Strawberry guava is typically the dominant species because it invades sites by seeds spread by pigs and reproduces vegetatively by root suckers. In places, taller introduced tree species are common. It is possible that shifts will eventually occur in the introduced species that dominate a site, particularly if tall stature, competitive tree species are present. This would not represent a transition to another state. Sites that are completely dominated by dense stands of strawberry guava typically show no indications (death or partial death of stands; emergence of potentially taller tree species) of yielding to change in the foreseeable future. A few remnant ohia lehua (*Metrosideros polymorpha*) trees may remain as emergents above the canopy of introduced species, but no seedlings or saplings are likely to be present. Depending on local seed sources, strawberry guava

(*Psidium cattleianum*) generally will become dominant over time. Taller statured introduced trees including tropical ash (*Fraxinus uhdei*) and paperbark (Melaleuca quinquinervia) are dominant on some sites. In places, black bamboo (*Phyllostachys nigra*) forms dense stands. Understory composition is like that of Community phase 2.1 except on sites that have an extremely dense, closed overstory canopy of species such as strawberry guava and black bamboo. Scattered individuals of native species such as hapuu (*Cibotium glaucum*) and uluhe (*Dicranopteris linearis*) may remain in the understory.

Dominant plant species

- African tuliptree (*Spathodea campanulata*), tree
- strawberry guava (*Psidium cattleianum*), tree
- soapbush (*Clidemia hirta*), shrub

State 4
Naturalized Grassland State

This state consists of three grassland community phases with little or no tree overstory. These phases are maintained by grazing, which keeps preferred species from becoming too tall, and adequate recovery periods, which ensure vigor and cover of preferred species. High production of preferred grass species and extensive cover allow for increased soil moisture retention, vegetative production, and overall soil quality. These factors are degraded by grazing practices that result in loss of preferred grass species leading to increase in less desirable grasses, weed invasion, and an increase in the extent of bare soil. Community phase 4.1, when subjected to continuous grazing that does not allow the preferred forage species to recover from defoliation, shifts to Community phase 4.2, which is dominated by lower value grass species but contains enough cover of preferred forages to allow for a shift back to Phase 4.1 with prescribed grazing. Longer-term continuous grazing leads to Community Phase 4.3, which consists of low value grass species and increasing cover of weedy shrubs and tree saplings. Improvement of this phase requires weed control followed by prescribed grazing. This state occurs mostly at lower elevations of the ecological site.

Community 4.1
Californiagrass/desmodium

Tree overstory is nonexistent or present with a canopy cover less than 25 percent. Where present, the overstory consists of ohia lehua (*Metrosideros polymorpha*) or introduced tree species. Californiagrass (*Urochloa mutica*) and guineagrass (*Urochloa maxima*) are common, preferred forage grass species. Pangolagrass (*Digitaria eriantha*), Dallis grass (*Paspalum dilatatum*), and Vasey’s grass (*P. urvillei*) have been established on some sites. Common legumes are desmodium (Desmodium spp.) and white clover (*Trifolium repens*).

Dominant plant species

- para grass (*Urochloa mutica*), grass
- ticktrefoil (*Desmodium*), other herbaceous

Community 4.2
Californiagrass – Hilograss/Colombian waxweed (tarweed)

This community phase is dominated by grass and grasslike species with lower forage value than those found in Phase 4.1. Cover of preferred forage grasses is still high enough to enable a shift back to phase 4.1 with improved management. Desirable legumes are greatly reduced in abundance or are no longer present. Cattle can be maintained on the lower value forages, but animal growth and vigor will be reduced. Also, the number of weedy species is high, and their stature, seed production potential, and wide distribution can lead to rapid increase and a shift to Community Phase 4.3 unless management is improved. Where present, the overstory consists of ohia lehua (*Metrosideros polymorpha*) or introduced tree species. Cover of desirable forage grasses ranges about 40 to 60 percent, having been partly replaced by Hilograss (*Paspalum conjugatum*). Weedy broomsedge bluestem (*Andropogon virginicus*) may have increased to 10 percent cover or more. Desirable legumes have become very rare. Undesirable forbs such as tarweed or Colombian waxweed (*Cuphea carthagenensis*) have become common.

Dominant plant species

- para grass (*Urochloa mutica*), grass
- hilograss (*Paspalum conjugatum*), grass
- Colombian waxweed (*Cuphea carthagenensis*), other herbaceous

Community 4.3
Hilograss – rat-tail grass/stickbush (false pikake)/black bamboo

This community phase is dominated by low value grasses, forbs, shrubs, and small trees. Improving the grazing regime is extremely unlikely to shift this phase to a more productive grassland phase due to the low cover of desirable species and the abundance of weeds. Frequent mowing is not worthwhile; it will keep shrubs and trees in check but will do little to improve the grass and forb community. Aggressive weed control treatments are needed to reduce weed abundance. Replanting of desired grass forage species may be needed, along with removal of livestock until desired species have reassumed dominance. There typically is a high population of stunted weedy trees and shrubs that is suppressed by heavy browsing and trampling and is poised to explode if animal use is reduced or removed. Seedlings and saplings of introduced species such as strawberry guava (*Psidium cattleianum*), common guava (*Psidium guajava*), tropical ash (*Fraxinus uhdei*), and paperbark (*Melaleuca quinquenervia*) are becoming common. In places, black bamboo (*Phyllostachys nigra*) begins to form dense stands. Cover of desirable grass species is about 20 percent or less. Common rush or Japanese mat rush (*Juncus effusus*) is become common, particularly in wetter spots. Broomsedge bluestem (*Andropogon virginicus*) is increasing. Low-quality forage grasses/grasslikes include common carpetgrass (*Axonopus fissifolius*), glenwoodgrass (*Sacciolepis indica*), shortleaf spikesedge (*Kyllinga brevifolia*), Egyptian grass (Dactyloctenium aegypticum), and smutgrass or rat-tail grass (Sporobolus africanus syn. S. indicus var. capensis). Strawberry guava (*Psidium cattleianum*) and common guava (*Psidium guajava*) may be more abundant than they appear if poorly-fed cattle have browsed their stems almost to ground level. If browsing stops, these species will rapidly take over a site. Sawtooth blackberry (*Rubus argutus*) forms scattered thickets. A large variety of weedy shrubs and forbs is present, e.g. false pikake (*Clerodendrum chinense*), spiny amaranth (*Amaranthus spinosus*), tarweed (*Cuphea carthagenensis*), lantana (*Lantana camara*), sensitive partridge pea (*Chamaecrista nictitans*), sensitive plant or shameplant (*Mimosa pudica*), and cane tibouchina (*Tibouchina herbacea*). Forage legumes have been eliminated.

Dominant plant species

- stickbush (*Clerodendrum chinense*), shrub
- hilograss (*Paspalum conjugatum*), grass
- rat-tail grass (*Sporobolus indicus var. capensis*), grass
- black bamboo (*Phyllostachys nigra*), grass

Pathway P4.1A
Community 4.1 to 4.2

This community phase degrades to Phase 4.2 by continuous grazing that weakens forage species in relation to less desirable forage species.

Pathway P4.2B
Community 4.2 to 4.1

Community phase 4.2 degrades to phase 4.3 by long-term continuous grazing that reduces cover and competitiveness of desirable forage grasses. The grassland becomes dominated by species of lesser or no forage value. There may be a large population of undesirable weedy shrubs and trees that is kept in check by heavy browsing and trampling pressure.

Pathway P4.2A
Community 4.2 to 4.3

Community phase 4.2 can be converted to phase 4.1 by prescribed grazing. A prescribed grazing plan provides for intensive but temporary grazing of grasslands that ensures that cattle consume some low-value forage species along with preferred forages and allows preferred forages time to recover from defoliation. The grazing plan may require splitting the herd, creating additional water sources, and creating multiple pastures by crossfencing. Invading broomsedge bluestem may be controlled by mowing their seed stalks before seed set and by liming to increase soil pH.

Pathway P4.3A
Community 4.3 to 4.2

Weed control measures, liming, and mechanical brush control can reduce the densities of weedy shrubs, forbs, and grasses and allow implementation of prescribed grazing.

Transition T1A
State 1 to 2

State 1, Reference, can transition to State 2 Invaded Understory, by gradual replacement of the native understory by introduced shrubs, vines, and small trees that outcompete the native understory species. This process is accelerated by ungulate foraging that disturbs the soil surface and directly destroys native plants and prevents their regeneration.

Transition T1B
State 1 to 4

State 1 Reference will transition to State 4 Naturalized Grassland by clearing the forest with heavy machinery. Desired forages such as Californiagrass (*Urochloa mutica*) or guineagrass (*Urochloa maxima*) may then be established, or less desirable grass and sedge species will establish on their own.

Restoration pathway R2A
State 2 to 1

It is possible to restore a facsimile of State 1 Reference State from State 2 Invaded Understory. Before restoration of native plants, introduced understory plants must be eliminated by weed control measures, and ungulates must be excluded from the restoration site by a suitable fence. Native species that have been eliminated or greatly reduced in numbers must be restored by replanting. Long-term control of weeds will be necessary.

Transition T2A
State 2 to 3

The large native ohia lehua and other tree species that form the overstory of State 2 Invaded Understory are unable to successfully regenerate due to the dense, shady understory of introduced species. Eventually the large native trees die and are replaced by introduced tree species.

Transition T2B

State 2 to 4

State 2 Invaded Understory State will transition to State 4 Naturalized Grassland by mechanical clearing. Introduced forage grasses may then be seeded or sprigged into the site. Weed control measures will be necessary before and during pasture establishment to control reemerging weed species.

Restoration pathway R3A
State 3 to 4

State 3 Invaded Over and Understory State may be restored to State 4 Naturalized Grassland by mechanical clearing of overstory and understory vegetation. Introduced forage grasses may then be seeded or sprigged into the site. Weed control measures will be necessary before and during forage establishment to control reemerging weed species.

Restoration pathway R4A
State 4 to 1

Restoration to State 1 Reference is possible by erecting an ungulate-proof fence, removing all domestic and feral ungulates, and intensive and long-term weed and brush control accompanying replanting of common native species. Restoration will be much more difficult if the site is in Community Phase 4.3, in which many fast-growing and competitive species such as strawberry guava and black bamboo are already strongly-established.

Transition T4A
State 4 to 3

State 4 Naturalized Grassland State will transition to State 3 Invaded Overstory and Understory by abandonment of cleared land, including removal of domestic cattle. However, if large numbers of feral cattle are present, the site may remain in State 4, Community Phase 4.3.

Additional community tables

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DEFINITIONS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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.

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

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

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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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John Proctor
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Acknowledgments

Assistance, advice, review, and/or insights:

Randy Bartlett, Puu Kukui Watershed Preserve
Alison Cohan, The Nature Conservancy
Michael Constantinides, NRCS-PIA
Gordon Cran, Kapapala Ranch
Diana Crow, Ulupalakua Ranch
Lance DeSilva, Hawaii DLNR
Kerri Fay, Waikamoi Preserve, The Nature Conservancy
Alex Franco, Kaupo Ranch
Ranae Ganske-Cerizo, NRCS
Carl Hashimoto, NRCS
Bob Hobdy, consultant, Maui

Wallace Jennings, NRCS
Mel Johansen, The Nature Conservancy
Jordan Jokiel, Haleakala Ranch
David Leonard, volunteer
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Reese Libby, GIS - NRCS
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Scott Meidel, Haleakala Ranch
Anna Palomino, Hoolawa Farms Inc.
Jon Price, USGS
Tamara Sherrill, USFWS, Maui Nui Botanical Garden
Amber Starr, Hana Ranch
Kahana Stone, NRCS
Mark Vaught, Water Resources, Alexander & Baldwin
Jacqueline Vega, NRCS
Rich von Wellsheim, Whispering Bamboos, Kipahulu

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	04/08/2026
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:**
