Natural Resources
Conservation Service

Ecological site VX160X01X007
Isothermic Ustic Naturalized Grassland (Kikuyugrass)

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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): 160X–Subhumid and Humid Intermediate and High Mountain Slopes

This MLRA occurs in the State of Hawaii on the Big Island of Hawaii and extent on Maui. Elevation ranges from 1000 to 9000 feet (305 to 2745 meters). Slopes are moderate to steep. Topography is sloping to hilly, and cinder cones are common. Lava flows are basaltic or andesitic aa or pahoehoe lava. Aa may form outcrops at higher elevations, but most of the area is covered with material weathered from deep volcanic ash. Areas of volcanic sand and gravel alluvium exist. Average annual precipitation ranges from 20 to 75 inches (510 to 1905 millimeters). Most of the rainfall occurs during kona storms from November through March. In some areas afternoon fog accumulation at higher elevations adds significant moisture to the soil by fog drip and ameliorates evapotranspiration. Average annual air temperatures range from 50 to 71 degrees F (10 to 22 degrees C), with little seasonal variation. The dominant soil order is Andisols with an isothermic or isomesic soil temperature regime and ustic or udic soil moisture regime. Native vegetation consists of forests and rangelands that can include medium to tall statured forests, savannas, and grasslands.

Classification relationships

This ecological site occurs within Major Land Resource Area (MLRA) 160 - MLRA 160XY – Subhumid and Humid Intermediate and High Mountain Slopes.

Ecological site concept

This ecological site occurs on the Island of Maui on the west- and south-facing slopes of

Haleakala, where it is accessible from the Haleakala Highway and Kula Highway south of the towns of Makawao and Pukalani. Most of the area is on lands owned by the State of Hawaii, the Division of Hawaiian Homelands, and private owners that include large ranches. It also occurs on southwest-facing slopes of Kohala, mauka and makai of the Waimea-Hawi Road (Rte. 250), and on the west-facing slopes of Mauna Kea south of Waimea along the upper highway (Rte. 190) including the area known as Mana. Large parts of it are on private lands managed for livestock grazing. The State of Hawaii and State Division of Hawaiian Homelands own large areas, and some parts are on the US Army Pohakuloa Training Area. Small, restored examples of native forest are found on the island of Hawaii on State and private lands in Kohala along the Waimea-Hawi highway, and at the Auwahi dryland forest restoration project on the southwestern slopes of Haleakala on the island of Maui.

The central concept of the Isothermic Ustic Naturalized Grassland is of well drained, shallow to very deep soils formed in deposits of volcanic ash. This site is primarily found where elevations range from 2000 to 4500 feet, and annual precipitation range between 20 to 40 inches. Annual air temperatures and rainfall are associated with warm (isothermic), seasonally dry (ustic) soil conditions. Soils at the northern extremes of the ecological site on both islands transition to moist (udic) soil conditions. The original vegetation was dry tropical forest with very high native species diversity; only remnants remain of this native forest. Most of the area is now naturalized grassland dominated by introduced species, mainly kikuyugrass (Cenchrus clandestinus) with minor amounts of leguminous forbs and vines.

Associated sites

VX167X01X001	**Oxidic Dissected Lowland** The Oxidic Dissected Lowland adjoins this ecological site on the north aspect of Haleakala. It is at generally lower elevations with higher rainfall, warmer temperatures, and much more weathered soil orders than this ecological site. The dominant forage species in the Oxidic Dissected Lowland is guineagrass rather the kikuyugrass. It probably supported a native forest of tall ohia with tree ferns in the past rather than the dry forest of this ecological site.
VX157X01X008	**Rocky Isothermic Naturalized Grassland Koa haole/guineagrass - buffelgrass/glycine (Leucaena leucocephala/Urochloa maxima - Cenchrus ciliaris/Neonotonia wightii)** The Rocky Isothermic Naturalized Grassland adjoins this ecological site on the lower western aspect of Haleakala on Maui. It occurs at lower, drier, and warmer elevations than this ecological site on similar volcanic ash soils. It has introduced vegetation dominated by kiawe and guinea grass and supported a sparser, lower-stature, more shrub-dominated native vegetation in the past, compared with this ecological site. Buffelgrass is also common in this ecological site where the two sites meet.

VX164X01X500	**Volcanic Ash Forest** The Volcanic Ash Forest adjoins this ecological site on the upper slopes of the southwest aspect of Kohala on Hawaii. It occurs at higher, cooler, moister elevations on similar volcanic ash parent materials to those on this ecological site and supports medium stature rain forest rather than dry forest species. There was probably a very diverse transitional dry-moist forest type where these two ecological sites merged; this zone is now a grassland of introduced species.
VX160X01X501	**Ustic Fog Drip Forest** The Ustic Fog Drip Forest adjoins this ecological site on the southwest aspect of Mauna Kea. It occurs at higher, moister, cooler elevations than this ecological site. The native species lists are different, but the two ecological sites share kikuyugrass as the dominant forage species over most of their areas. The Ustic Fog Drip Forest has some cool-season (C3) grass species not found in this ecological site.
VX160X01X502	**Isomesic-Cool Isothermic Forest** The Isomesic Cool Isothermic Forest adjoins this ecological site on the western aspects of Haleakala and Mauna Kea. The Isomesic Cool Isothermic Forest occurs at mostly higher, moister, cooler elevations than this ecological site. The Isomesic Cool Isothermic Forest is dominated by tall koa trees rather than the dry forest species, including koaia, of this ecological site. Where the sites meet, koa and koaia may intermix and possibly even hybridize, as evidenced by seed pods with intermediate characteristics of the two species.
VX157X01X003	**Rocky Volcanic Ash Savanna Kiawe/buffelgrass (Prosopis pallida/Pennisetum ciliare)** The Rocky Volcanic Ash Savanna adjoins this ecological site on the lower western aspect of Haleakala on Maui and the lower southwestern slopes of Kohala and western slopes of Mauna Kea on Hawaii. It occurs at lower, drier, and warmer elevations than this ecological site on similar volcanic ash parent materials. It has introduced vegetation dominated by kiawe and buffelgrass and supported a sparser, lower-stature, more shrub-dominated native vegetation in the past, compared with this ecological site. Buffelgrass is also common in this ecological site where the two sites meet.

Similar sites

VX161B01X500	**Ustic Isothermic Forest** The Ustic Isothermic Forest occurs on Hawaii at similar elevations, climate, and on similar soils to this ecological site. Both sites support remnants of a notably diverse dry native forest type, and both are now primarily naturalized grasslands dominated by kikuyugrass and, on Hawaii, crimson fountaingrass.

Table 1. Dominant plant species

Tree	Not specified
Shrub	Not specified

Herbaceous	(1) *Pennisetum clandestinum*

Legacy ID

R160XY007HI

Physiographic features

This ecological site occurs on lava flows on sloping mountainsides of shield volcanoes. Lava flows are aa (loose, cobbly) or pahoehoe (smooth, relatively unbroken).

Table 2. Representative physiographic features

Landforms	(1) Shield volcano > Mountain slope
Runoff class	Very low to medium
Flooding frequency	None
Ponding frequency	None
Elevation	610–1,372 m
Slope	2–40%
Water table depth	152 cm
Aspect	W, SE, S, SW

Table 3. Representative physiographic features (actual ranges)

Runoff class	Very low to high
Flooding frequency	None
Ponding frequency	None
Elevation	305–1,829 m
Slope	0–50%
Water table depth	152 cm

Climatic features

Summary for this Ecological Site
Average annual precipitation ranges from 25 to 29 inches (635 to 735 millimeters). Most precipitation occurs from October through April. Average annual temperature ranges from 64 to 69 degrees F (18 to 20 degrees C).

Table 4. Representative climatic features

Frost-free period (characteristic range)	365 days
Freeze-free period (characteristic range)	365 days
Precipitation total (characteristic range)	635-737 mm
Frost-free period (actual range)	365 days
Freeze-free period (actual range)	365 days
Precipitation total (actual range)	610-762 mm
Frost-free period (average)	365 days
Freeze-free period (average)	365 days
Precipitation total (average)	686 mm

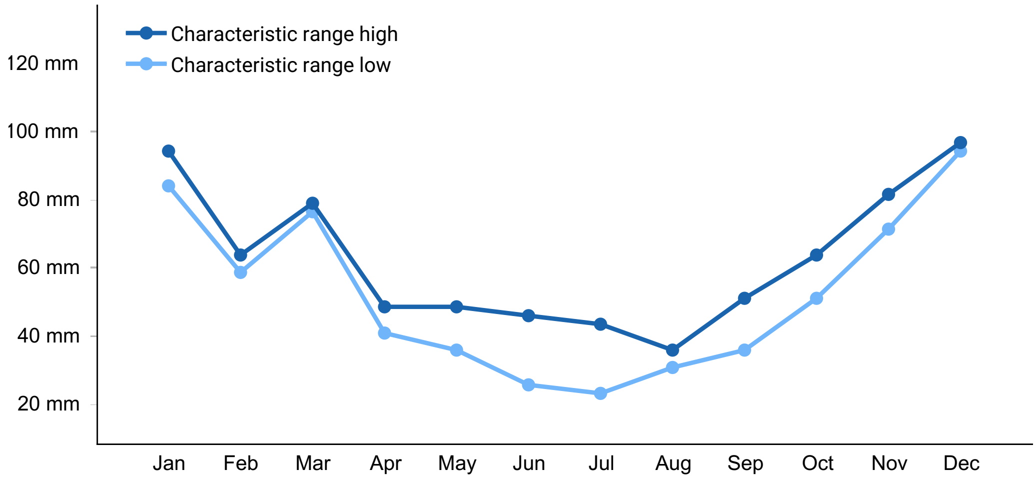

Figure 1. Monthly precipitation range

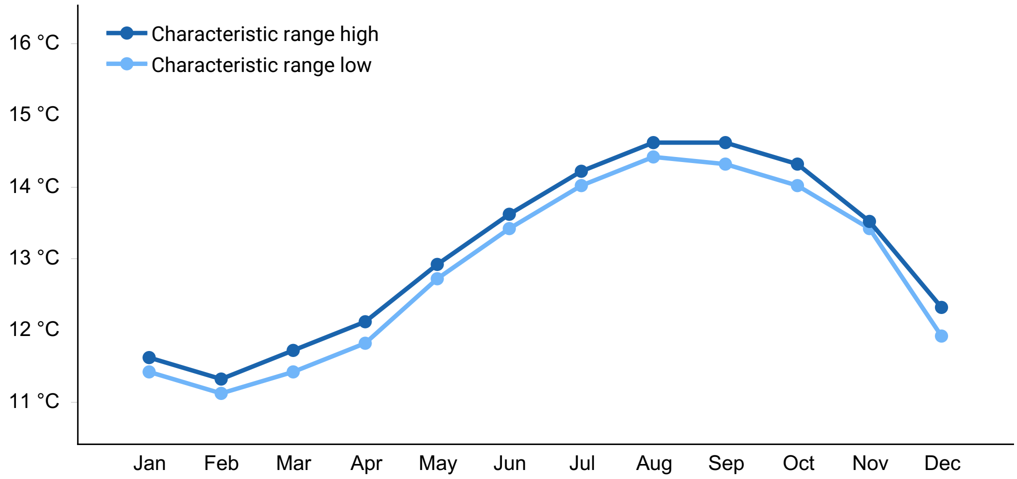

Figure 2. Monthly minimum temperature range

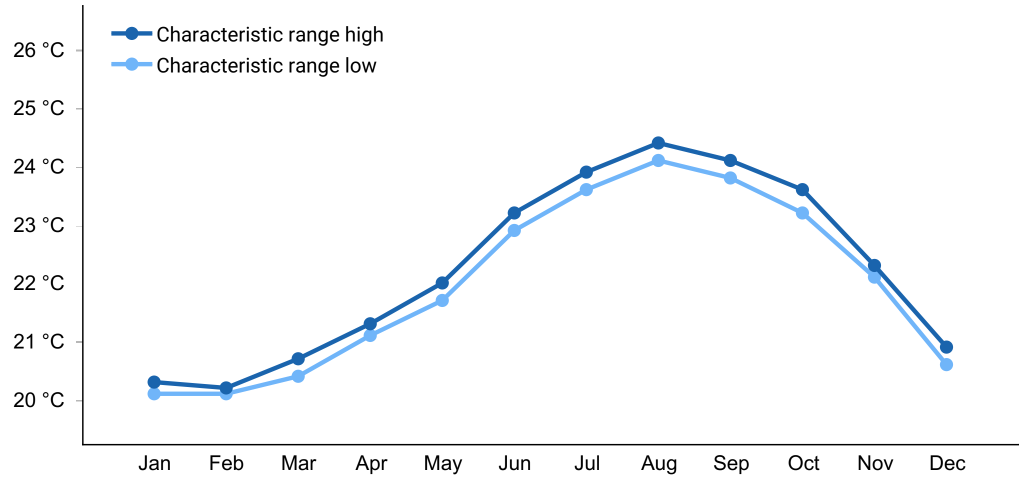

Figure 3. Monthly maximum temperature range

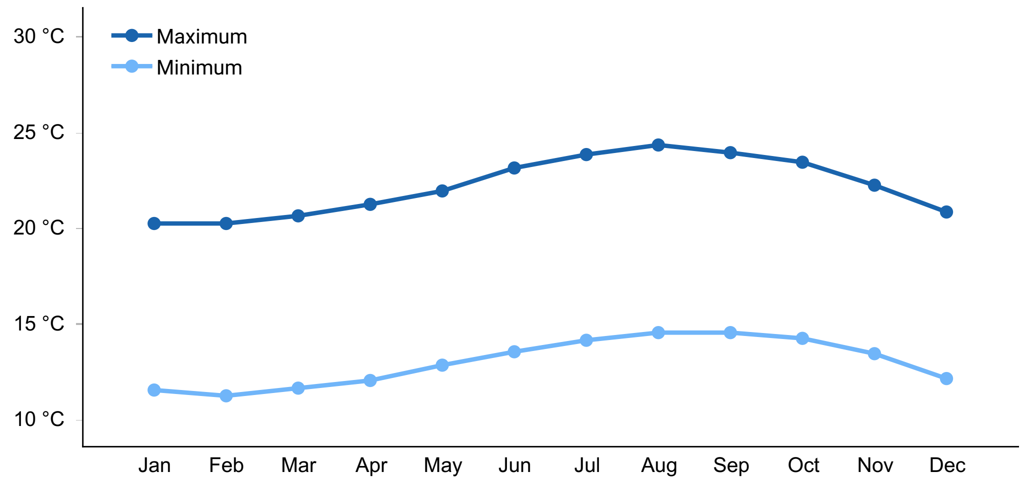

Figure 4. Monthly average minimum and maximum temperature

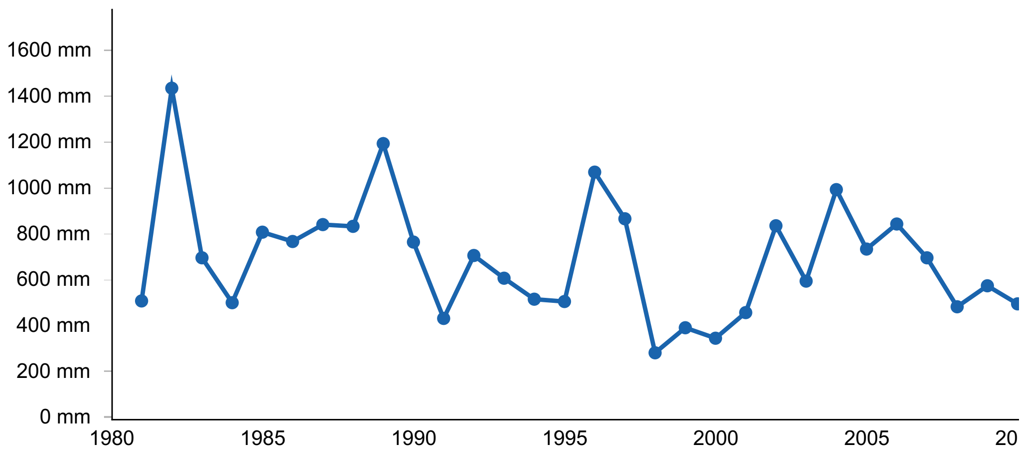

Figure 5. Annual precipitation pattern

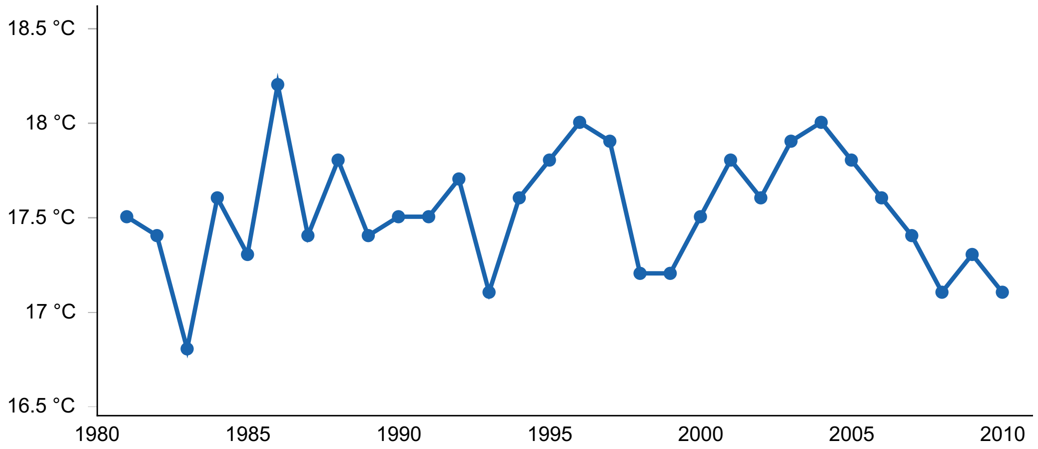

Figure 6. Annual average temperature pattern

Climate stations used

- (1) KULA HOSPITAL 267 [USC00515004], Kihei, HI
- (2) KULA BRANCH STN 324.5 [USC00515000], Kula, HI

Influencing water features

There are ephemeral, seasonal, and some permanent streams carrying water from the ecological site mauka (above) this one that have formed gulches. The gulches are vegetated with species typical of the rest of the ecological site. Some of these gulches still support a high diversity of remnant native species. One example of this can be observed in the Koaia Tree Sanctuary on the island of Hawaii, which is accessed from Kohala Mountain Road.

Soil features

All soil series correlated with this ecological site have isothermic (warm) soil temperature regimes and ustic soil moisture regimes (in most years, dry for more than 90 cumulative days but less than 180 days). Surface soil pH ranges from 5.9 to 7.6; extreme pH of subsurface soils within 30 inches (75 centimeters) of the surface ranges from 6.3 to 8.2. All soils are in the Andisols soil order.

Soils in this ecological site are mineral soils formed from volcanic ash deposited over lava. The exception are Kamakoa soils, which developed in flood plains and are weathered from alluvial volcanic ash. Kamakoa soils differ from the other soils in the ecological site by having accumulations of calcium carbonate in subsurface horizons as well as higher salinity (EC range is 8 to 16). These conditions occur at depths below 34 inches (85 cm), so are unlikely to greatly affect plant growth conditions.

The volcanic ash soils of Hawaii are derived mostly from basaltic ash that varies relatively little in chemical composition (Hazlett and Hyndman 1996; Vitousek 2004). Most of these soils are classified today as Andisols, which have these general management 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).

Table 5. Representative soil features

Parent material	(1) Volcanic ash–basalt
Surface texture	(1) Medial very fine sandy loam (2) Medial loam (3) Medial silt loam
Drainage class	Well drained
Permeability class	Moderate to rapid
Soil depth	84–165 cm
Surface fragment cover <=3"	2–25%
Surface fragment cover >3"	1–30%
Available water capacity (0-101.6cm)	5.08–27.94 cm
Calcium carbonate equivalent (0-101.6cm)	0–5%
Electrical conductivity (0-101.6cm)	0–4 mmhos/cm
Sodium adsorption ratio (0-101.6cm)	0–20
Soil reaction (1:1 water) (0-25.4cm)	5.9–7.6
Subsurface fragment volume <=3" (0-152.4cm)	2–25%
Subsurface fragment volume >3" (0-152.4cm)	2–40%

Table 6. Representative soil features (actual values)

Drainage class	Well drained to excessively drained
Permeability class	Very slow to rapid

Soil depth	38–183 cm
Surface fragment cover <=3"	2–25%
Surface fragment cover >3"	1–40%
Available water capacity (0-101.6cm)	5.08–27.94 cm
Calcium carbonate equivalent (0-101.6cm)	0–10%
Electrical conductivity (0-101.6cm)	0–16 mmhos/cm
Sodium adsorption ratio (0-101.6cm)	0–150
Soil reaction (1:1 water) (0-25.4cm)	5.6–8.4
Subsurface fragment volume <=3" (0-152.4cm)	2–36%
Subsurface fragment volume >3" (0-152.4cm)	2–75%

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.

This ecological site is currently a patchwork of naturalized species that reflect either grassland or forest depending on the pattern of disturbance and/or management. The primary land use at this time is grazing land and these grasslands consist of tall warm-season species that are primarily naturalized to the site.

The original vegetation was dry tropical forest with very high native species diversity; only remnants remain of this historic native forest state. Because very little of the original native vegetation remains, the reference state of this ecological site consists of the dominant naturalized grassland vegetation state, mainly kikuyugrass (Cenchrus clandestinus) with minor amounts of leguminous forbs and vines. Kikuyugrass provides excellent forage but is very competitive with other vegetation and can carry intense wildfires. Glycine (*Neonotonia wightii*), a valuable leguminous forage vine, is very competitive and can completely cover other vegetation when not controlled by grazing resulting in one of the community phases in the reference state which primarily occurs on Maui around Kula. With abandonment, these naturalized grasslands convert to a weed-invaded state of introduced, trees, shrubs, and forbs that are not readily grazed or browsed by livestock.

Since its introduction on the island of Hawaii in 1926 and rapid spread in the 1960s, crimson fountaingrass (Cenchrus setaceus) may form a state there with nearly monospecific stands or may be interspersed with islands of buffelgrass (Cenchrus ciliaris) in the lower-drier areas. Although fountaingrass is competitive, the main reason few other plants fit into the concept of this state is the frequency and intensity of fires promoted by fountaingrass, which eliminates most other plants.

Humans have altered this site considerably, starting with the native Hawaiian settlers as they brought plants with them and opened lands up for agriculture. With the removal of the native forest, introduction of non-native species, and then the later practices of livestock ranching, and development, the site has undergone many changes over the last 150 years.

Natural Disturbances

The natural (not human-caused) disturbances most important for discussion in this ecological site are lava flows, natural fires, and volcanic ash falls.

A lava flow obviously destroys all the vegetation it covers. There are flows crossing this ecological site that range from 750 to 13,000 years old; it is possible that new lava flows will occur here again. Lava flows may ignite fires, particularly in dense, introduced vegetation such as kikuyugrass or fountaingrass. Fires started by lightning may occur occasionally.

Vegetation can be killed by erupted layers of ash from volcanic vents, depending on the temperature of the ash and the depth of accumulation. However, vegetation sometimes survives ash flows (Vitousek 2004). Vegetation can recover rapidly because ash flow deposits possess physical and chemical properties favorable to plant growth, including high water holding capacity, high surface area, rapid weathering, and favorable mineral nutrient content. The succession process relies heavily on adjacent ecosystems. A steady rain of organic material, seeds, and spores slowly accumulates in cracks and pockets along with tiny fragments of the new lava surface. On Hawaiian lava flows, primary succession proceeds more rapidly on wet windward slopes, but more slowly in dry areas. New soils develop very rapidly in ash deposits, and further soil development is facilitated in turn by the rapidly-developing vegetation (Shoji et al. 1993). Future ash falls may occur here; past ash flows are old enough for soils and vegetation to have developed on them.

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% 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% of lowlands may have been altered (Athens 1997).

By the time of European contact late in the 18th century, the Polynesians had developed high population densities and placed extensive areas under intensive agriculture (Cuddihy and Stone 1990). Prehistoric native lowland forest disturbance can be attributed to clearing for agriculture by hand or by fire, introduction of new plants, diseases, and animals, and wood harvesting (Athens 1997). On the island of Hawaii large-scale historic Hawaiian dry land farming (such as the Leeward Kohala Field System which covers an area of 60 km2) as well as the use of flow irrigation (South Kohala Field Systems) overlapped large portions of this ecological site. Kohala is unique in that these ditches sometimes extended across valley slopes to the dry ridge lands that separated these drainages. On the island of Maui the remains of large cultivation systems have been identified within this ecological site around Kula and Kahikinui where early Hawaiians farmed dry land taro and sweet potato, gathered wood and hunted for pigs and birds (Kagawa and Vitousek 2012). Parts of this ecological site occur at elevations as low as 1,000 feet and may have been affected by fires or other human-caused disturbances.

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. Most, and probably all, of the native reference community phase is currently disturbed by humans or has been restored approximately within the past few decades.

State and transition model

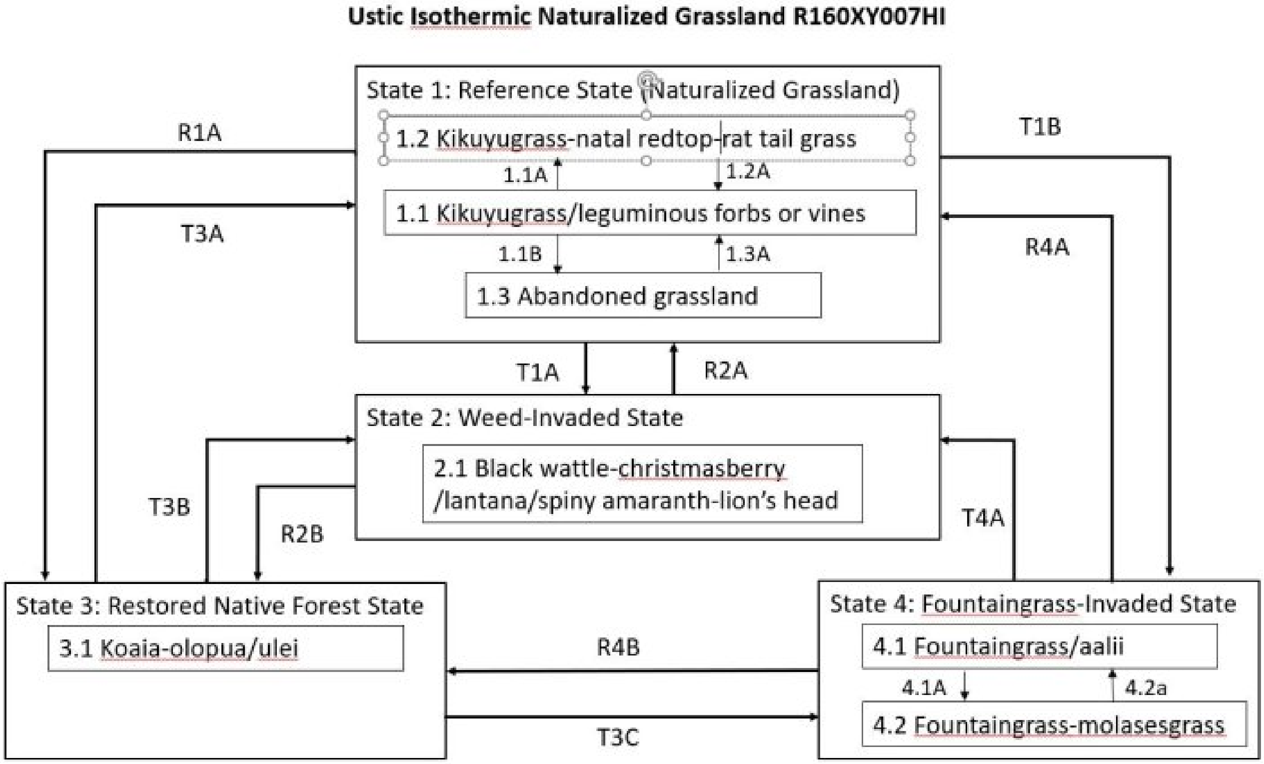

Figure 7. STM for R160XY007HI (Isothermic Ustic Naturalized Grassland)

T1A - State 1 Reference will transition gradually to State 2 Weed-Invaded by invasion of competitive tree and shrub species, particularly black wattle, lantana, and christmasberry. The rate of conversion will depend on proximity of weed seed sources and the degree of overgrazing that creates bare soil and reduces the competitiveness of kikuyugrass.

R1A - State 1 Reference may be restored to a facsimile of the original native forest. The site must be securely fenced to exclude all domestic and feral ungulates; protection from fire is also useful. Managed grazing outside the restoration site to control dense growth of grasses can reduce fire threat. Within the enclosure, introduced plants must be cut down, girdled, or killed with weed control measures. Replanting of native species then proceeds along with continuous weed monitoring and control. Supplemental water is usually needed until native plants are well established.

T1B - State 1 Reference can transition to State 4 Fountaingrass-Invaded when competitiveness of kikuyugrass is reduced by overgrazing, allowing less-desirable fountaingrass (Cenchrus setaceus) to invade and establish. Eventually fountaingrass will carry a fire through the site, eliminating all other species with the possible exception of aalii (Dodonaea viscosa).

R2A - Restoration of State 2 Weed-Invaded to State 1 Reference requires brush control followed by weed control. Re-establishment of desired forage grasses is likely to be needed.

R2B - State 2 Weed-Invaded may be restored to a facsimile of native forest by constructing a fence designed to keep out ungulates (including deer, pigs, goats, and cattle), removal of all ungulates, establishment of fire protection, brush control, intensive and long term weed control, all followed by replanting of native species.

T3A - This transition from State 3 Restored Native Forest to State 1 Naturalized Grassland is not recommended given the rarity of locations containing native plant species. It would occur quickly and easily by allowing ungulates and/or fire to access a site surrounded by State 1.

T3B - State 3 Restored Native Forest gradually transitions to State 2 Weed-Invaded due to lack of native plant regeneration resulting from weed competition and ungulate browsing coupled with destruction of existing native plants by ungulates. The transition is rapid when fire carried by introduced grass species destroys other vegetation.

T3C - State 3 Restored Native Forest transitions to State 4 Fountaingrass-Invaded if fountaingrass (Cenchrus setaceus) invades the site. Competition from fountaingrass would impede growth and reproduction of native species; eventually fountaingrass will carry a fire through the site, eliminating all other species with the possible exception of aalii (Dodonaea viscosa).

R4A - We are unaware of this restoration having been performed. Fountaingrass might be heavily grazed and then killed with probably two applications of herbicide, with follow-up control of seedling emergence from the fountaingrass seed bank and introduction of a competitive desired grass species. Careful grazing, protection from fire, and continuous control of seedling fountaingrass from nearby areas may result in success.

R4B - Grazing, mowing, or weed-whacking of fountaingrass followed by applications of herbicide to kill existing fountaingrass plants and follow-up herbicide to kill fountaingrass recruited from the site seedbank or nearby areas would be necessary. Dead fountaingrass plants and litter should be left in place to protect the soil from erosion. Planting of native plants could then proceed along with protection from ungulates and fire.

Figure 8. Transition Legend for R160XY007HI (Isothermic Ustic Naturalized Grassland)

P1.1A - Kikuyugrass cover and vigor are reduced by continuous grazing. This allows less desirable forage species such as natal redtop (Melnis repens), rat-tail grass (Sporobolus africanus syn. S. indicus var. capensis) and barbwiregrass (Cymbopogon refractus) to increase. Glycine may also increase under overgrazed conditions.

P1.1B - This phase will change to 1.3 Abandoned grassland when ungulate foraging is absent or too light to control glycine growth.

P1.2A - A grazing plan is needed that provides for appropriate stocking rate and a system that allows pastures adequate time to recover following a grazing event. A period of deferment may also be helpful. Desirable grass species are still present and able to recover with proper management. The grazing plan may require adjusting the herd, creating additional water sources, and creating multiple pastures by cross-fencing. Weed control may be necessary to eliminate some species such as inedible shrubs.

P1.3A - Pastures that have been abandoned are often dominated by unpalatable species or palatable species which are overgrown and is not desirable. Kikuyu grass loses quality when it is old and will not be readily consumed. Secondary compounds such as condensed tannins increase in glycine as it ages beyond 75 days reducing its palatability. Mowing or prescribed burning to reduce the unpalatable biomass can help return it to productive pasture. Alternatively, livestock grazing can be used but stock will likely need to be supplemented to avoid detriment to animal health and performance.

Figure 9. Community Pathways Legend of State 1 (Reference State) for R160XY007HI (Isothermic Ustic Naturalized Grassland).

P4.1A - This community phase consists of lower-value grass species that become abundant upon continuous heavy grazing of fountaingrass. Further overgrazing exacerbates this process, causing a state transition to State 2 Weed-Invaded.

Typically little or no overstory vegetation exists in this community phase. Planted eucalyptus stands exist in some areas. Jaraguagrass or thatchinggrass (Hyparrhenia rufa), barbwiregrass (Cymbopogon refractus), molassesgrass (Melinis minutiflora), Natal redtop or rose Natal grass (Melinis repens), beardgrasses (Bothriochloa spp.), and lesser amounts of low-vigor buffelgrass (Cenchrus ciliaris) dominate.

P4.2A - Phase 4.2 can change to phase 4.1 by application of a prescribed grazing program that allows fountaingrass to reassume dominance. Weed control may be necessary if taller weedy forbs and/or shrubs are abundant.

Figure 10. Community Pathways Legend of State 4 (Fountaingrass-Invaded State) for R160XY007HI (Isothermic Ustic Naturalized Grassland).

State 1
Reference State

This state consists of three community phases. Although formerly in forest vegetation, most of this ecological site is now covered by naturalized grassland. There is an almost continuous cover of grass with no or few trees, shrubs, and forbs. Few plants reproduce or survive in stands of highly-competitive kikuyugrass. Intense fires can be carried by kikuyugrass, both aboveground and in belowground plant parts. Community phase 1.1 consists primarily of kikuyugrass and leguminous forbs and vines. With intense or continuous grazing of livestock, a shift to phase 1.2 occurs, in which desirable forages are overgrazed and undesirable plants begin to increase. Phase 1.1 can shift to Phase 1.3 Abandoned Grassland, in which glycine vines cover the ground, shrubs, and trees. This shift is due to lack of grazing.

Community 1.1
Kikuyugrass/leguminous forbs or vines

Figure 11. Reference State 1.1. Kikuyugrass/leguminous forbs and vines. Near Kula on Maui. John Proctor.

Figure 12. Reference State 1.1. Kikuyugrass/leguminous forbs and vines. Near Kula on Maui. John Proctor.

This community phase is dominated by an almost continuous cover of kikuyugrass (*Pennisetum clandestinum* or synonym Cenchrus clandestinus) with an admixture of desirable leguminous forbs or vines. There is little or no overstory in this community phase. In wetter areas white clover (*Trifolium repens*) is the dominant forb. In drier areas greenleaf desmodium (Desmodium spp.), kaimi clover (*Desmodium incanum*), bur clover (*Medicago polymorpha*), black medic (*Medicago lupulina*) or tineroo glycine (*Neonotonia wightii*) are the dominant forbs or vines. Other common legumes may include common vetch (Vicia spp.) and yellow and white sweet clover (Melilotus spp.). At higher elevations of the ecological site, C3 or cool-season grasses such as common velvet grass (*Holcus lanatus*) and orchardgrass (*Dactylis glomerata*) also occur and can become co-dominant if grazed appropriately. Natal red top (*Melinis repens*), guinea grass (Megathyrsus maximus) and buffelgrass (Cenchrus ciliaris) can occur at the lowest elevation, driest parts of the ecological site.

Dominant plant species

- kikuyugrass (*Pennisetum clandestinum*), grass
- perennial soybean (*Neonotonia wightii*), other herbaceous
- white clover (*Trifolium repens*), other herbaceous
- ticktrefoil (*Desmodium*), other herbaceous
- zarzabacoa comun (*Desmodium incanum*), other herbaceous
- black medick (*Medicago lupulina*), other herbaceous

Community 1.2
Kikuyugrass – natal redtop - rat-tail grass

Figure 13. Reference State 1.2. Heavily grazed kikuyugrass with fireweed or synonym Madagascar ragwort, Kohala SW aspect. David Clausnitzer.

Figure 14. Reference State 1.2. Barbwiregrass invading a pasture of relatively intact Kikuyugrass on Maui. Pane silt loam, 7-25 % slopes. Elevation ~ 2,800 ft. NE aspect. John Proctor. 5/24/22.

Figure 15. Reference 1.2. A monoculture of Sourgrass has replaced kikuyugrass in this pasture near Ulupalakua on Maui. Io silt loam, 7-25% slopes. Elevation ~ 1,900 ft. West to southwest aspect. John Proctor. 5/9/22.

This community phase consists primarily of a combination of kikuyugrass and undesirable grass species. Weedy shrubs and forbs can be abundant. Tree and native plant regeneration are sparse to nonexistent due to fires and damage by ungulates. There is little or no overstory in this community phase, although black wattle (*Acacia mearnsii*) or christmasberry (*Schinus terebinthifolius*) may invade. Kikuyugrass, natal redtop (*Melinis repens*) and rat-tail grass (Sporobolus africanus syn. S. indicus var. capesnsis) are typically the most abundant grasses. On Maui, sourgrass (*Digitaria insularis*) and barbwiregrass (Cybopogon refractus) are becoming increasingly more invasive in disturbed areas at the lower elevations of this ecological site where they are possibly favored more in the silt loam soils. A diverse assemblage of weedy, introduced shrubs and forbs is found scattered through the grass stands. Common shrubs are 'a'ali'i (Dodonea viscosa), lantana (*Lantana camara*), christmasberry (*Schinus terebinthifolius*), panini cactus (Opuntia spp.), haole koa (*Leucaena leucocephala*), tree poppy (Bocconia frutesens) and tree daisy (*Montanoa hibiscifolia*). Among the common forb species are Fireweed also known as Madagaascar ragwort (Senicio madagascariensis), Sacramento bur (*Triumfetta semitriloba*), common cocklebur (*Xanthium strumarium*), spiny amaranth (*Amaranthus spinosus*), and false ragweed (*Parthenium hysterophorus*).

Resilience management. Panini cactus (Opuntia spp) is currently more problematic/abundant on Maui than it is on the Big Island. Prior to the 1949 introduction of biocontrol insects, panini cactus infested 66,000 acres of Parker Ranch rangelands on the Big Island which resulted in successful establishment of a fungus and three introduced insects. While one of the biocontrol insects (cactoblastis moth) is known on Maui, there is no record of other biocontrol agents being released there which may be why panini is more prevalent there.

Dominant plant species

- kikuyugrass (*Pennisetum clandestinum*), grass
- rose Natal grass (*Melinis repens*), grass
- elongate dropseed (*Sporobolus elongatus*), grass

Community 1.3
Abandoned Grassland

Figure 16. Reference State 1.3 Abandoned Grassland. Glycine vines smothering christmas berry. Haleakala, SW aspect. David Clausnitzer, 7/22/08.

This community phase occurs when grazing by livestock is abandoned. It is expressed differently depending on the species present. Glycine is a preferred leguminous forage that is capable of enveloping grasses, shrubs, and small to medium trees and killing them when not controlled. Where glycine is present, it can increase and smother other vegetation (most prevalent around Kula, Maui). Where glycine is absent, kikuyu grass thatch can build up to 24 inches thick and becomes a serious fire risk under dry conditions.

Molasses grass may also invade an un-grazed site. Where other shrubs occur, their density can increase, especially if there is ungulate wildlife that graze the grass preferentially.

Dominant plant species

- perennial soybean (*Neonotonia wightii*), other herbaceous

Pathway P1.1A
Community 1.1 to 1.2

Kikuyugrass/leguminous forbs or vines

Kikuyugrass – natal redtop - rat-tail grass

Kikuyugrass cover and vigor are reduced by continuous grazing. This allows less desirable forage species such as natal redtop (Melnis repens), rat-tail grass (Sporobolus africanus syn. S. indicus var. capensis) and barbwiregrass (*Cymbopogon refractus*) to increase. Glycine may also increase under overgrazed conditions.

Pathway P1.1B
Community 1.1 to 1.3

Kikuyugrass/leguminous forbs or vines

Abandoned Grassland

This phase will change to 1.3 Abandoned grassland when ungulate foraging is absent or too light to control glycine growth.

Pathway P1.2A
Community 1.2 to 1.1

Kikuyugrass – natal redtop - rat-tail grass

Kikuyugrass/leguminous forbs or vines

A grazing plan is needed that provides for appropriate stocking rate and a system that allows pastures adequate time to recover following a grazing event. A period of deferment may also be helpful. Desirable grass species are still present and able to recover with proper management. The grazing plan may require adjusting the herd, creating additional water sources, and creating multiple pastures by cross-fencing. Weed control may be necessary to eliminate some species such as inedible shrubs.

Pathway P1.3A
Community 1.3 to 1.1

Abandoned Grassland

Kikuyugrass/leguminous forbs or vines

Pastures that have been abandoned are often dominated by unpalatable species or palatable species which are overgrown and is not desirable. Kikuyu grass loses quality when it is old and will not be readily consumed. Secondary compounds such as condensed tannins increase in glycine as it ages beyond 75 days reducing its palatability. Mowing or prescribed burning to reduce the unpalatable biomass can help return it to productive pasture. Alternatively, livestock grazing can be used but stock will likely need to be supplemented to avoid detriment to animal health and performance.

State 2
Weed-Invaded State

This state consists of one community phase. It is dominated by competitive, introduced, weedy species of trees, shrubs, and forbs that are not readily grazed or browsed by livestock.

Community 2.1
Black wattle - christmasberry/lantana/spiny amaranth - lion's head

Figure 17. Weed-Invaded State 2.1. Closeup. Kohala, S aspect. David Clausnitzer, 4/14/09.

Figure 18. Weed-Invaded State 2.1. Monotypic stand of Lion's head (Leonotis nepetifolium). Lower Kula Rd. Pane silt loam, 7 to 25% slopes. 2,400 ft. John Proctor. 6/3/22.

Figure 19. Weed-Invaded State 2.1. Monotypic stand of Black Waddle south of Kula on Maui. Kula loam, 12-20% slopes. West aspect. Elevation 2,900 ft. John Proctor. 5/9/22.

This phase develops by overgrazing that reduces desirable forages and allows for establishment of opportunistic woody species. Left untreated the woody species will increase in size and density and take over the site. Common invasive trees in this phase are black wattle (*Acacia mearnsii*), silk oak (*Grevillea robusta*), christmasberry or Brazilian peppertree (*Schinus terebinthifolius*), jacaranda (*Jacaranda mimosifolia*), and camphor tree (*Cinnamomum camphora*). Common shrubs are lantana (*Lantana camara*), panini (Opuntia spp.), sand mallow (Sidastrum micranthum) and tree daisy (*Montanoa hibiscifolia*). Among the common forb species are fireweed (Senicio madagascariensis), Sacramento bur (*Triumfetta semitriloba*), common cocklebur (*Xanthium strumarium*), spiny amaranth (*Amaranthus spinosus*) and false ragweed (*Parthenium hysterophorus*). On Maui, Lion's head (Leonotis nepetifolium) is an undesirable forb which is becoming increasingly more invasive in disturbed sites at lower elevations resulting in serious negative impacts to ranch productivity.

Dominant plant species

- black wattle (*Acacia mearnsii*), tree
- Brazilian peppertree (*Schinus terebinthifolius*), tree
- lantana (*Lantana camara*), shrub
- spiny amaranth (*Amaranthus spinosus*), other herbaceous
- Christmas candlestick (*Leonotis nepetifolia*), other herbaceous

State 3
Restored Native Forest State

This state consists of one community phase. Intact examples of the original native plant community no longer exist. This description is compiled from field observations of restored sites and protected patches, isolated plants on disturbed sites, historical accounts, and examination of remnant vegetation in shallow ravines. It is thought that the species found in these ravines are like those that previously existed on the uplands (McEldowney 1983). The largest remnant example currently has a high percent canopy cover of koaia (*Acacia koa*ia). This may be due to the ability of koaia to reproduce and grow quickly in disturbed, sunny situations when protected from browsing animals. The original community may have had less koaia cover and more cover of other species. There are accounts of koaia having been present in the middle of the 20th century on areas of this ecological site on the slopes of Mauna Kea (Billy Paris, rancher, personal communication). There also are a few naturally-occurring koaia on older soils on Puuanahulu near Puuwaawaa, in the southern extreme of this ecological site on Hawaii, and at some locations on Maui (Bob Hobdy, personal communication). Analysis of prehistoric land snail shells on Hawaii suggests that much of the original vegetation may have been like the xerophytic forest found near Puuwaawaa (Christensen 1983). Olopua (*Nestegis sandwicensis*) is thought to been a large component of this ecological site on the island of Maui (Pers. Comms. to Jennifer Higashino). This medium sized tree was common in dry forests throughout the islands of Hawaii especially at elevations between 1,000-4,200 ft. The general appearance of this phase is an open to nearly closed canopy of low to medium height trees, a shrub understory, and a ground layer of vines, grasses, and sedges.

Community 3.1
Koaia-olopua/ulei

Figure 20. Restored Native Forest State 3.1. Koaia stand with kikuyugrass, protected by fence. SW aspect Kohala. Soil map unit 418, Waimea medial silt loam, 12 to 20 percent slopes. David Clausnitzer, 8/22/06.

Figure 21. Restored Native Forest State 3.1. Koaia stand with kikuyugrass, protected by fence. SW aspect Kohala. Soil map unit 459, Kemole stony medial silt loam, 12 to 20 percent slopes. David Clausnitzer, 4/14/09.

Figure 22. Restored Native Forest State 3.1. Koaia stand with kikuyugrass, protected by fence. David Clausnitzer, 8/22/06.

The lack of intact examples of this forest makes full description impossible. Joseph Rock (1913) considered this forest type to be one of the most species-rich in the Hawaiian Islands, comparable to the area on and around Puuwaawaa cone on the Island of Hawaii. This was true on both deeper, volcanic ash soils and on younger lava flows. However, the “semi-dry” area near Makawao, on the north end of this ecological site on Maui, may have been less rich in species because, being climatically transitional to the rain forest zone, it was unsuitable for some of the species found elsewhere (Rock 1913). There is a wide array of potential overstory tree species in this phase. Ohia lehua (*Metrosideros polymorpha*) probably occurred, being most abundant at the moister extremes of the ecological site. Koa (*Acacia koa*) would have been present, especially near boundaries with adjoining higher-elevation ecological sites on Haleakala and Mauna Kea that were dominated by koa. Koa is not known to occur naturally in Kohala on Hawaii and probably did not occur in that part of the ecological site. Species associated with dry to semi-dry environments would have occurred, for example, kauila (both *Alphitonia ponderosa* and *Colubrina oppositifolia*), lama (*Diospyros sandwicensis*), mehamehame (*Flueggea neowawraea*), olopua (*Nestegis sandwicensis*), and ohe makai (Polyscias sandwicensis), among many others. Alahee (*Psydrax odorata*) would have been a common small tree. Halapepe (*Pleomele auwahiensis* on Maui, *P. hawaiiensis* on Hawaii) formerly was common but is now rare. Other small to medium stature tree species are koaia (*Acacia koa*ia), (*Zanthoxylum hawaiiense*), aiea (*Nothocestrum latifolium*), kolea (*Myrsine lanaiensis* and *M. lessertiana*), mao hau hele (*Hibiscus brackenridgei*), and sandalwood (*Santalum ellipticum* and, at higher elevations, *S. freycinetianum* on Maui and *S. paniculatum* on Hawaii). The ground level understory may have been sparse as in other Hawaiian dry forests, containing (or formerly containing), for example, vines such as hue hue (*Cocculus orbiculatus*), awikiwiki (*Canavalia hawaiiensis*), and kupala (*Sicyos pachycarpus*), shrubs such as ilima (*Sida fallax*), aweoweo (*Chenopodium oahuense*), and akia (*Wikstroemia monticola* on Maui and *W. phillyreifolia* and *W. pulcherrima* on Hawaii), and grasses such as *Panicum pellitum*, *Panicum konaense*, and several species of Eragrostis.

Dominant plant species

- koaoha (*Acacia koaia*), tree
- Hawai'i olive (*Nestegis sandwicensis*), tree
- Hawai'i hawthorn (*Osteomeles anthyllidifolia*), shrub

State 4
Fountaingrass-Invaded State

This state consists of two community phases that have continuous grass cover with no or very few trees, shrubs, or forbs. Fountaingrass (Cenchrus setaceus) may form nearly monospecific stands or may be interspersed with islands of buffelgrass (Cenchrus ciliaris) in drier areas. Although fountaingrass is competitive, the main reason few other plants fit into the concept of this state is the frequency and intensity of fires promoted by fountaingrass, which eliminates most other plants. With low fire frequency, koa haole

(*Leucaena leucocephala*) and bush indigo (*Indigofera suffruticosa*) may be present. Persistent searching in fountaingrass stands may even reveal seedlings of native trees such as wiliwili (*Erythrina sandwicensis*), but they are unlikely to survive very long. The indigenous shrub aalii (*Dodonaea viscosa*) can survive in habitats with that burn frequently. With continuous heavy grazing, particularly by cattle, fountaingrass will decrease. Koa haole and bush indigo (*Indigofera suffruticosa*) also will decrease under heavy grazing pressure. Increasers include jaraguagrass or thatchinggrass (*Hyparrhenia rufa*), barbwiregrass (*Cymbopogon refractus*), molassesgrass (*Melinis minutiflora*), Natal redtop or rose Natal grass (*Melinis repens*), bluestems (Bothriochloa spp.), and lesser amounts of buffelgrass and weedy forbs. With severe deterioration, shrubby species such as lantana (*Lantana camara*) and apple of Sodom (Solanum linnaeaum) increase. Shortgrasses such as Bermudagrass (*Cynodon dactylon*), kikuyugrass, low-vigor buffelgrass, and weedy annual forbs become more abundant, as well as lesser amounts of pricklypear cactus or Barbary fig (*Opuntia ficus-indica*). Pricklypear cactus abundance has been limited by an introduced biocontrol insect.

Community 4.1
Crimson fountaingrass-buffelgrass

Figure 23. Fountaingrass-Invaded State 4.1. Mix of fountaingrass and buffelgrass. Mauna Kea S aspect. Generic photo, David Clausnitzer.

Figure 24. Fountaingrass-Invaded State 4.1. Fountaingrass with aalii. Mauna Kea S aspect. Generic photo, David Clausnitzer.

This plant community is dominated by an almost continuous cover of fountaingrass interspersed with patches of buffelgrass. Buffelgrass is a more desirable forage species and is usually overgrazed in preference to fountaingrass. Very few trees, shrubs, vines, or forbs are found in this plant community. Koa haole and glycine (*Neonotonia wightii*), both desirable forage species, often are present outside the fence lines of grazed fountaingrass pastures. Typically little or no overstory vegetation exists in this community phase. Planted eucalyptus stands exist in some areas. Crimson fountaingrass typical is 70 to 95 percent of total plant community composition by weight. Buffelgrass makes up 0 to 10 percent of total composition.

Dominant plant species

- crimson fountaingrass (*Pennisetum setaceum*), grass
- buffelgrass (*Pennisetum ciliare*), grass

Community 4.2
Crimson fountaingrass - molassesgrass

Figure 25. Fountaingrass-Invaded State 4.2. Fountaingrass with molassesgrass. Mauna Kea S aspect. Generic photo, David Clausnitzer.

This community phase consists of lower-value grass species that become abundant upon continuous heavy grazing of fountaingrass. Further overgrazing exacerbates this process, causing a state transition to State 2 Weed-Invaded. Typically little or no overstory vegetation exists in this community phase. Planted eucalyptus stands exist in some areas. Jaraguagrass or thatchinggrass (*Hyparrhenia rufa*), barbwiregrass (*Cymbopogon refractus*), molassesgrass (*Melinis minutiflora*), Natal redtop or rose Natal grass (*Melinis repens*), beardgrasses (Bothriochloa spp.), and lesser amounts of low-vigor buffelgrass (Cenchrus ciliaris) dominate.

Dominant plant species

- crimson fountaingrass (*Pennisetum setaceum*), grass
- molassesgrass (*Melinis minutiflora*), grass

Pathway P4.1A
Community 4.1 to 4.2

Crimson fountaingrass-buffelgrass

Crimson fountaingrass - molassesgrass

This community phase consists of lower-value grass species that become abundant upon continuous heavy grazing of fountaingrass. Further overgrazing exacerbates this process, causing a state transition to State 2 Weed-Invaded. Typically little or no overstory vegetation exists in this community phase. Planted eucalyptus stands exist in some areas. Jaraguagrass or thatchinggrass (*Hyparrhenia rufa*), barbwiregrass (*Cymbopogon *refractus*), molassesgrass (*Melinis minutiflora*), Natal redtop or rose Natal grass (*Melinis repens*), beardgrasses (Bothriochloa spp.), and lesser amounts of low-vigor buffelgrass (Cenchrus ciliaris) dominate.

Pathway P4.2A
Community 4.2 to 4.1

Crimson fountaingrass - molassesgrass

Crimson fountaingrass-buffelgrass

Phase 4.2 can change to phase 4.1 by application of a prescribed grazing program that allows fountaingrass to reassume dominance. Weed control may be necessary if taller weedy forbs and/or shrubs are abundant.

Transition T1A
State 1 to 2

State 1 Reference will transition gradually to State 2 Weed-Invaded by invasion of competitive tree and shrub species, particularly black wattle, lantana, and christmasberry. The rate of conversion will depend on proximity of weed seed sources and the degree of overgrazing that creates bare soil and reduces the competitiveness of kikuyugrass.

Restoration pathway R1A
State 1 to 3

State 1 Reference may be restored to a facsimile of the original native forest. The site must be securely fenced to exclude all domestic and feral ungulates; protection from fire is also useful. Managed grazing outside the restoration site to control dense growth of grasses can reduce fire threat. Within the enclosure, introduced plants must be cut down, girdled, or killed with weed control measures. Replanting of native species then proceeds along with continuous weed monitoring and control. Supplemental water is usually needed until native plants are well established.

Transition T1B
State 1 to 4

State 1 Reference can transition to State 4 Fountaingrass-Invaded when competitiveness of kikuyugrass is reduced by overgrazing, allowing less-desirable fountaingrass (Cenchrus setaceus) to invade and establish. Eventually fountaingrass will carry a fire through the site, eliminating all other species with the possible exception of aalii (*Dodonaea viscosa*).

Restoration pathway R2A
State 2 to 1

Restoration of State 2 Weed-Invaded to State 1 Reference requires brush control followed by weed control. Re-establishment of desired forage grasses is likely to be needed.

Restoration pathway R2B
State 2 to 3

State 2 Weed-Invaded may be restored to a facsimile of native forest by constructing a fence designed to keep out ungulates (including deer, pigs, goats, and cattle), removal of all ungulates, establishment of fire protection, brush control, intensive and long term weed control, all followed by replanting of native species.

Transition T3A
State 3 to 1

This transition from State 3 Restored Native Forest to State 1 Naturalized Grassland is not recommended given the rarity of locations containing native plant species. It would occur quickly and easily by allowing ungulates and/or fire to access a site surrounded by State 1.

Transition T3B
State 3 to 2

State 3 Restored Native Forest gradually transitions to State 2 Weed-Invaded due to lack of native plant regeneration resulting from weed competition and ungulate browsing coupled with destruction of existing native plants by ungulates. The transition is rapid when fire carried by introduced grass species destroys other vegetation.

Transition T3C
State 3 to 4

State 3 Restored Native Forest transitions to State 4 Fountaingrass-Invaded if fountaingrass (Cenchrus setaceus) invades the site. Competition from fountaingrass would impede growth and reproduction of native species; eventually fountaingrass will carry a fire through the site, eliminating all other species with the possible exception of aalii (*Dodonaea viscosa*).

Restoration pathway R4A
State 4 to 1

We are unaware of this restoration having been performed. Fountaingrass might be heavily grazed and then killed with probably two applications of herbicide, with follow-up control of seedling emergence from the fountaingrass seed bank and introduction of a competitive desired grass species. Careful grazing, protection from fire, and continuous control of seedling fountaingrass from nearby areas may result in success.

Restoration pathway T4A
State 4 to 2

State 4 Fountaingrass-Invaded will transition gradually to State 2 Weed-Invaded by invasion of competitive tree and shrub species, particularly black wattle, lantana, and christmasberry. the rate of conversion will depend on proximity of weed sources, the degree of fire suppression, and the degree of overgrazing that creates bare soil and reduces the competitiveness of fountaingrass.

Restoration pathway R4B
State 4 to 3

Grazing, mowing, or weed-whacking of fountaingrass followed by applications of herbicide to kill existing fountaingrass plants and follow-up herbicide to kill fountaingrass recruited from the site seedbank or nearby areas would be necessary. Dead fountaingrass plants and litter should be left in place to protect the soil from erosion. Planting of native plants could then proceed along with protection from ungulates and fire.

Additional community tables

Other references

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

Aa lava: A type of basaltic lava having a rough, jagged, clinkery surface and a vesicular interior.

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

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

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.

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.

Isomesic soil temperature regime: A regime in which mean annual soil temperature is 47 degrees F (8 degrees C) or higher but lower than 59 degrees F (15 degrees C) and mean summer and mean winter soil temperatures differ by less than 11 degrees F (6 degrees C) at a specified depth.

Isothermic soil temperature regime: A regime in which mean annual soil temperature is 59 degrees F (15 degrees C) or higher but lower than 72 degrees F (22 degrees C) and mean summer and mean winter soil temperatures differ by less than 11 degrees F (6 degrees C) at a specified depth.

Major Land Resource Area (MLRA): A geographic area defined by NRCS that is characterized by a particular pattern of soils, climate, water resources, and land uses. The island of Hawaii contains nine MLRAs, some of which also occur on other islands in the state.

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

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

Medial: A “soil texture modifier” for volcanic ash soils having a water content at the crop wilting point of 30 to 100 percent; a soil that holds an amount of water intermediate to “hydrous” or “ashy” soils.

Naturalized plant community: A community dominated by adapted, introduced species. It is a relatively stable community resulting from secondary succession after disturbance. Most grasslands in Hawaii are in this category.

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

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.

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.

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.

R160XY007HI Isothermic Ustic Naturalized Grassland Annotated References

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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	05/21/2025
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):**

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5. **Number of gullies and erosion associated with gullies:**

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6. **Extent of wind scoured, blowouts and/or depositional areas:**

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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:**

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11. **Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site):**

---

12. **Functional/Structural Groups (list in order of descending dominance by above-ground annual-production or live foliar cover using symbols: >>, >, = to indicate much greater than, greater than, and equal to):**

    Dominant:

    Sub-dominant:

    Other:

Additional:

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

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

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

16. **Potential invasive (including noxious) species (native and non-native). List species which BOTH characterize degraded states and have the potential to become a dominant or co-dominant species on the ecological site if their future establishment and growth is not actively controlled by management interventions. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants. Note that unlike other indicators, we are describing what is NOT expected in the reference state for the ecological site:**

17. **Perennial plant reproductive capability:**