Ecological site VX166X01X001
Isohyperthermic Torric Naturalized Grassland

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General information

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

MLRA notes

Major Land Resource Area (MLRA): 166X–Very Stony Land and Rock Land

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

Classification relationships

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

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

Moku Acres on Molokai: Kona (2,196).

Moku Acres on Oahu: Ko'olaupoko (1,561).

Moku Acres on Lanai: Lahaina (412).

Ecological site concept

This ecological site is largely naturalized grassland and savanna on the northeastern shore of Lanai, the leeward shores of Molokai, and the extreme eastern tip of Oahu. Most of the area is owned by the City and County of Honolulu, large private ranches and land companies, Division of Hawaiian Homelands, and small private holdings. Access is limited but may be possible on the coastal road at the eastern tip of Oahu.

The central concept of the Isohyperthermic Torric Naturalized Grassland Ecological Site is of well drained, deep, Andisols and Entisols (fluvents) formed in deposits of volcanic ash, cinders and tuff or alluvium derived from those materials or alluvium derived from general volcanic materials. Annual air temperatures and rainfall are associated with very warm (isohyperthermic), usually dry (torric) soil conditions (USDA-SCS, 1972). Elevations range from sea level (0 meters) to about 200 feet (61 meters), with extreme examples up to 400 feet (122 meters). Because very little of the original native vegetation remains, the Reference State of this ecological site consists of the dominant, naturalized grassland vegetation. The dominant grass species is buffelgrass (*Pennisetum ciliare*). Common naturalized trees are kiawe (*Prosopis pallida*) and white leadtree or koa haole (*Leucaena leucocephala*).

The original native vegetation was dry coastal savanna (Egler, 1947; Wagner et al., 1999). Some common species, based on the current environment and remnant occurrences, were wili wili (*Erythrina sandwicensis*), naio (*Myoporum sandwicense*), Florida hopbush or a’alii (*Dodonaea viscosa*), yellow ‘ilima (*Sida fallax*), sandmat (Chamaesyce spp.), and native grasses.

Associated sites

VX158X01X002	**Isohyperthermic Torric Naturalized Grassland Kiawe/buffelgrass (Prosopis pallida/Pennisetum ciliare)** Some boundaries of the Isohyperthermic Torric Naturalized Grassland Ecological Site (R158XY002HI) near the coast adjoin this ecological site. R158XY002HI occurs overwhelmingly in uplands but the soils with which it is correlated reach the coast in many areas. It differs by having soils which are mostly Mollisols rather than the Andisols and Entisols (fluvents) which occur in this ecological site. The two ecological sites support similar vegetation in these coastal areas.

Table 1. Dominant plant species

Tree	(1) *Prosopis pallida*
Shrub	Not specified
Herbaceous	(1) *Pennisetum ciliare*

Legacy ID

R166XY001HI

Physiographic features

This ecological site occurs on volcanic ash or alluvium deposited on alluvial fans at the foot of sloping mountainsides of shield volcanoes (USDA-SCS, 1972). The water table is deeper than 72 inches (183 centimeters).

Table 2. Representative physiographic features

Landforms	(1) Shield volcano > Alluvial fan (2)
Runoff class	Low to medium
Flooding frequency	None to occasional
Ponding frequency	None
Elevation	0–61 m
Slope	0–25%
Water table depth	183 cm
Aspect	W, NE, E, S

Table 3. Representative physiographic features (actual ranges)

Runoff class	Not specified
Flooding frequency	Not specified

Ponding frequency	Not specified
Elevation	0–122 m
Slope	Not specified
Water table depth	Not specified

Climatic features

SUMMARY FOR THIS ECOLOGICAL SITE

Rainfall statistics were determined from University of Hawaii's Rainfall Atlas Raster Data (Giambelluca et al., 2013). Most of the precipitation falls from October through April. Representative (20th and 80th percentiles) values for annual average precipitation range from 15 to 29 inches (380 to 735 millimeters) while actual (10th and 90th percentiles) values range from 14 to 31 inches (355 to 790 millimeters). Extreme values range from 9 to 46 inches (230 to 1,170 millimeters). The mean annual precipitation is 21 inches (530 millimeters), and the median annual average precipitation is 18 inches (460 millimeters).

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

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

Conditions typically are very dry. Rainfall occurs as occasional light trade wind showers that drift over from the windward side of the island and as heavier rainfall during major winter storms. Major storms are important for soil moisture recharge, and the number of major storms is highly variable; drought can result from a winter with few or no storms. Due to the latitude, daylength varies little during the year, resulting in only about a 50 percent variation in solar energy input between June maximum to December minimum; this variation is somewhat less than that found in the continental United States (USDA-SCS, 1972; Western Regional Climate Center, 2020).

GENERAL PRINCIPLES

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

Hawaiian indigenous understanding recognized two seasons: Kau or Kauwela (dry season), and Ho`oilo (wet season). During Kau, the sun is directly overhead, days are long and warm, and the trade winds are stronger and more consistent; Kau started on the first new moon in May when the Pleiades set at sunrise (Handy et al., 1991). During Ho’oilo (wet season) the sun is declined toward the south, days are shorter, temperatures cooler and winds more variable and generally started with the first new moon in November. Ho’oilo is also the season when extensive low-pressure systems often approach the islands from the west, producing heavy rainstorms that primarily affect the leeward sides, but can envelope the entire island. (Malo, 1903; Handy et al., 1991; Sanderson, 1993). Differences in rainfall amounts between winter and summer are most marked in low elevation dry areas; wetter areas exhibit less seasonal variation in rainfall (USDA-SCS, 1972; Western Regional Climate Center, 2020).

The islands lie within the trade wind zone. Moisture is picked up from the ocean by trade winds to an altitude of about 6,000 feet (1,830 meters). As the trade winds from the northeast are forced up the islands’ mountains their moisture condenses, creating rain on the windward slopes; the leeward sides of the island receive little of this moisture. On Molokai, Oahu, and Lanai, where the mountains are all lower than 6,000 feet (1,830 meters), the highest rainfall amounts occur along or near the summits. The moist trade winds usually flow across these lower mountains and around the higher mountains. Lanai is sheltered from the trade winds by the much larger island of Maui, putting it in a rain shadow during trade wind weather; rainfall on Lanai is uncharacteristically low for Hawaii (USDA-SCS, 1972; Western Regional Climate Center, 2020).

Besides the trade winds discussed above, other rainfall sources on the Hawaiian Islands include: a) “Naulu storms” (Leopold, 1948) caused by local convergence of sea breezes and trade winds to produce summertime cumulus clouds, resulting in infrequent, short-duration, high-intensity rainfall and afternoon shade over leeward dry areas; and b) Fog drip, particularly important to areas with relatively low rainfall, that adds a significant amount of water to areas where clouds intersect mountains (Juvik and Nullet,1993; Western Regional Climate Center, 2020).

The heaviest rains are brought by winter storms. The greatest amounts of storm rainfall do not always occur in areas with the highest average rainfall, and a storm may bring half of the mean annual rainfall to a dry area in one day.

Table 4. Representative climatic features

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

Precipitation total (characteristic range)	381-737 mm
Frost-free period (actual range)	365 days
Freeze-free period (actual range)	365 days
Precipitation total (actual range)	356-787 mm
Frost-free period (average)	365 days
Freeze-free period (average)	365 days
Precipitation total (average)	533 mm

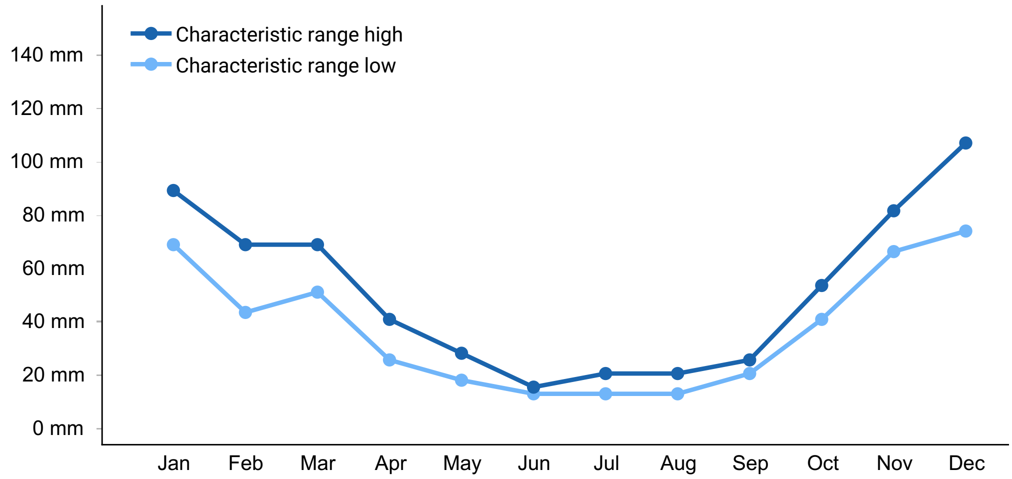

Figure 1. Monthly precipitation range

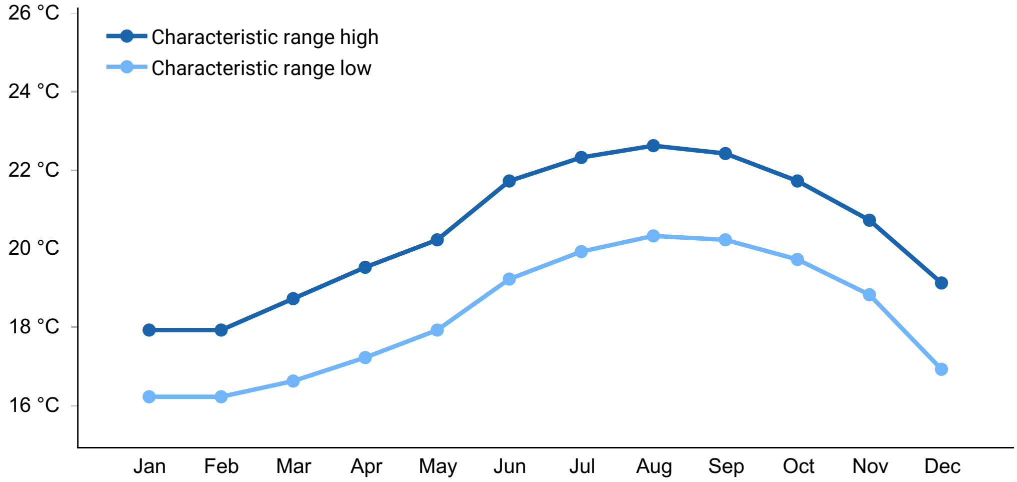

Figure 2. Monthly minimum temperature range

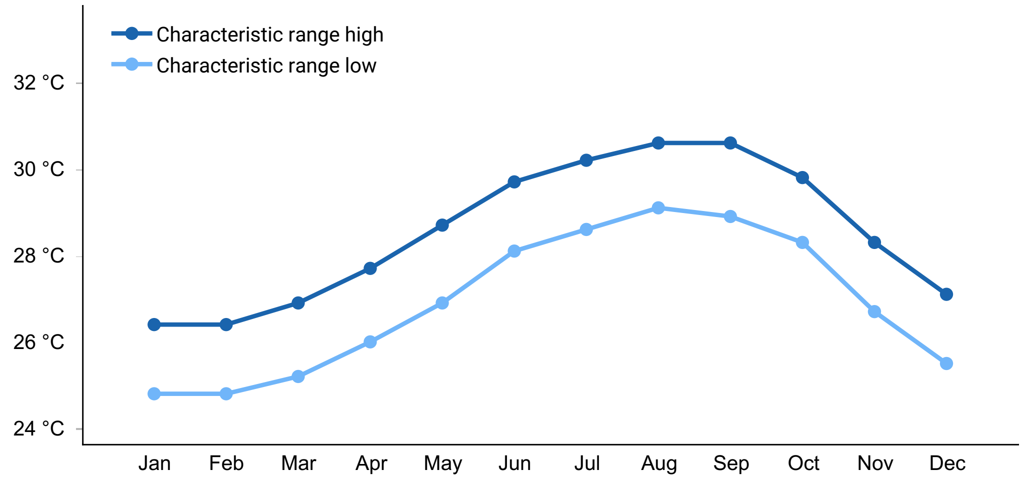

Figure 3. Monthly maximum temperature range

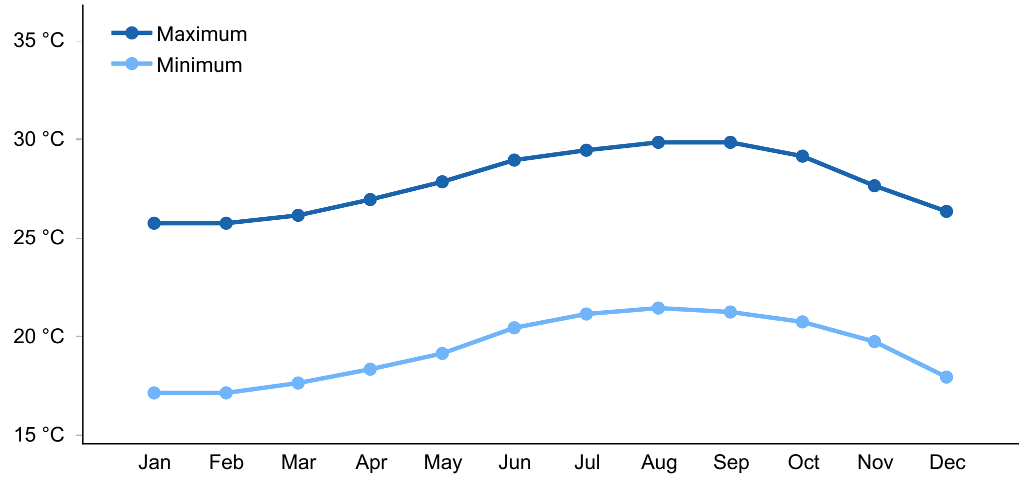

Figure 4. Monthly average minimum and maximum temperature

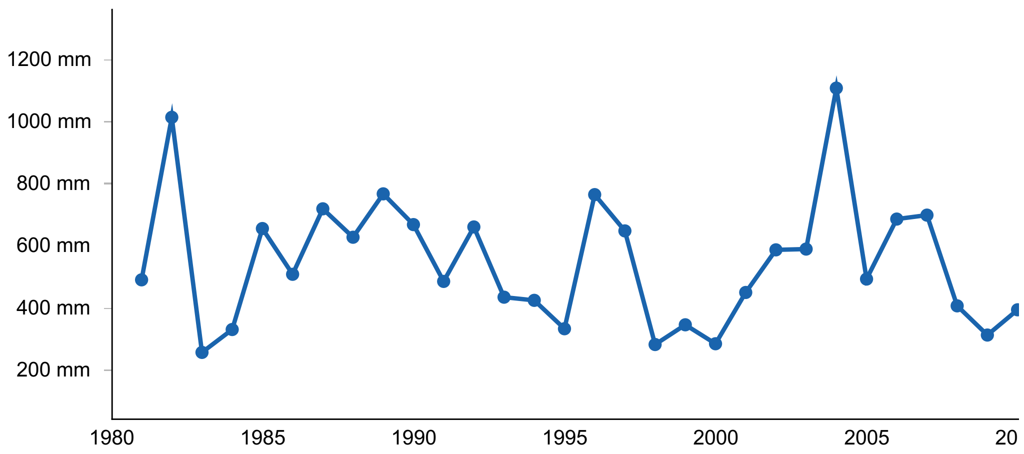

Figure 5. Annual precipitation pattern

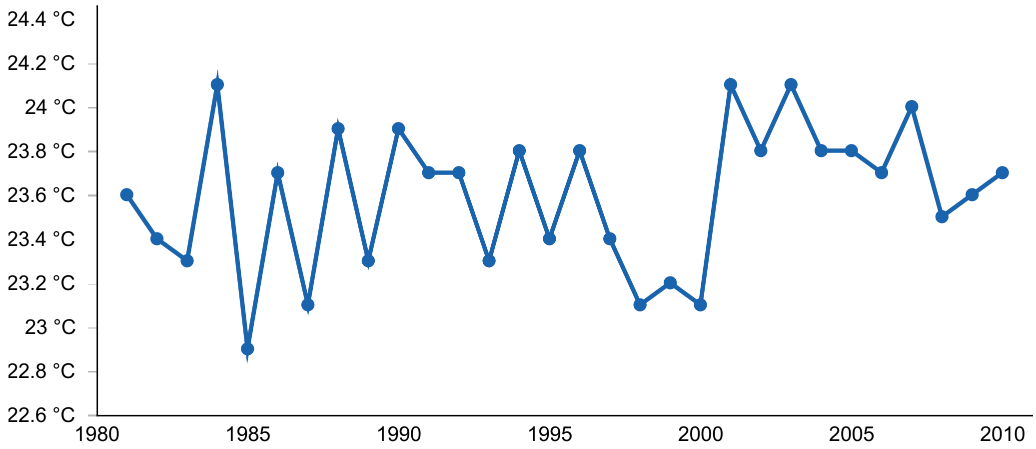

Figure 6. Annual average temperature pattern

Climate stations used

- (1) WAIKIKI 717.2 [USC00519397], Honolulu, HI
- (2) LANAI AP 656 [USC00515275], Lanai City, HI
- (3) MOLOKAI AP [USW00022534], Hoolehua, HI

Influencing water features

Many areas are on alluvial fans or within drainage channels that may occasionally flood after heavy rains (USDA-SCS, 1972).

Number of National Wetland Inventory (NWI) features overlapping ecological site: Riverine (78), freshwater forested/shrub wetland (25), estuarine and marine wetland (13), freshwater pond (11), freshwater emergent wetland (10), and estuarine and marine deepwater (9) (USFWS, 2023).

Number of National Hydrologic Dataset (NHD) features overlapping ecological site: Lake/pond (12), reservoir (7), and sea/ocean (3) (USGS, 2019).

Soil features

The soil components associated with this ecological site are Koko and Mala.

They are mineral soils that originally formed in volcanic ash, cinders, and tuff or in alluvium derived from general volcanic materials (USDA-SCS, 1972). Soil temperature regimes are isohypothermic (very warm). Soil moisture regimes are torric (in normal years, dry for more than half of the growing season and moist for less than 90 consecutive days during the growing season). All the soils are well drained, and deep or very deep. Surface soil pH from ranges from 6.3 to 7.0; extreme pH in subsurface soils within 20 inches (51 centimeters) of the surface are up to 7.0.

Koko soils are classified as Torrands, or Andisols with an aridic soil moisture regime. They are deep (typically about 48 inches or 122 centimeters) soils. They originally formed in volcanic ash, cinders, and tuff on alluvial fans and volcanic cones (USDA-SCS, 1972).

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 volcanic ash 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).

Soils of the Mala series are classified as Fluvents, which are soils deposited by moving water that have little or no profile development. this groundwater is slightly saline (electrical conductivity is 0 to 4 dS/m). Occasionally, they may flood after heavy rains (USDA-SCS, 1972).

Table 5. Representative soil features

Parent material	(1) Volcanic ash (2) Alluvium
Surface texture	(1) Silt loam (2) Silty clay
Family particle size	(1) Fine (2) Medial
Drainage class	Well drained
Permeability class	Very slow to slow
Depth to restrictive layer	122–183 cm
Soil depth	122–183 cm
Surface fragment cover <=3"	6–60%
Surface fragment cover >3"	0–2%
Available water capacity (0-101.6cm)	12.7–17.78 cm
Calcium carbonate equivalent (0-101.6cm)	0–99%
Electrical conductivity (0-101.6cm)	0–4 mmhos/cm

Sodium adsorption ratio (0-101.6cm)	0
Soil reaction (1:1 water) (0-25.4cm)	6.3–7
Subsurface fragment volume <=3" (15.2-152.4cm)	Not specified
Subsurface fragment volume >3" (0-101.6cm)	0–2%

Ecological dynamics

The information in this ecological site description (ESD), including the state-and-transition model (STM), was developed using archaeological and historical data, professional experience, and scientific studies. The information is representative of a complex set of plant communities. Not all scenarios or plants are included. Key indicator plants, animals, and ecological processes are described to inform land management decisions.

Natural Disturbances

There have been few lava flows or heavy volcanic ash flows on this ecological site that are recent enough to have affected the current vegetation and soils. Strong storms may sometimes cause flooding and soil erosion. Because this ecological site occurs at very low elevations along the coast, spray from the ocean deposits salts on the ground and on vegetation (USDA-SCS, 1972). Fires started by lightning probably do not occur (Abrahamson, 2013).

Human Disturbances

Human-related disturbances have been more important than natural disturbances in this ecological site since the arrival of Polynesians and, later, Europeans. This is reflected in the state-and-transition model diagram.

Humans arrived in the Hawaiian Islands 1,200 to 1,500 years ago. Their population gradually increased so that by 1,600 A.D. at least 80 percent of all the lands in Hawaii below about 1,500 feet (roughly 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). By the time of European contact late in the 18th century, the Polynesians had developed high population densities and placed large areas under intensive agriculture (Cuddihy and Stone, 1990). However, this ecological site was probably too dry for agriculture, except possibly burning to favor the growth of tanglehead or pili grass (*Heteropogon contortus*) used for thatching.

Prehistoric native lowland forest disturbance can be attributed to clearing for agriculture by hand or by fire, introduction of new plants, animals, possibly plant diseases, and wood harvesting. The introduced Pacific rat would have eaten bird eggs, invertebrates, and the seeds of native plants (Athens, 1997).

After the arrival of Europeans, documentary evidence attests to accelerated and extensive deforestation, erosion, siltation, and changes in local weather patterns (Kirch, 1983) due to more intensive land use, modern tools, and introduction of more plant, animal, and microbe species. Introduced kiawe trees (*Prosopis pallida*) are widespread in this ecological site.

The Polynesians introduced dogs, Pacific rats, and small pigs to the islands. After European discovery, cattle, sheep, horses, goats, and larger European pigs were introduced in the final decades of the 18th century. These animals ranged free on the islands, becoming very numerous and destructive by the early decades of the 19th century. Additionally, packs of feral dogs had become established, as confirmed by reports of their depredations on sheep. By 1851, records reported severe overstocking of pastures, lack of fences, and large numbers of feral livestock (Henke, 1929).

Through the 20th and into the 21st centuries, increases in human populations with attendant land development, as well as accelerated introduction of non-native mammals (including deer), birds, reptiles, amphibians, invertebrates, plants, and microorganisms, have brought about dramatic changes to wild ecosystems in Hawaii. Much of the original forest of this ecological site has been cleared and planted with introduced grasses for livestock grazing, and the remaining native plant communities have been highly disturbed.

Much of this ecological site has been used for homesites and other structures (USDI-USGS, 2006). The most common human-related disturbances on undeveloped areas are probably fires, grazing and browsing by feral ungulates, and soil erosion from denuded soils.

State and transition model

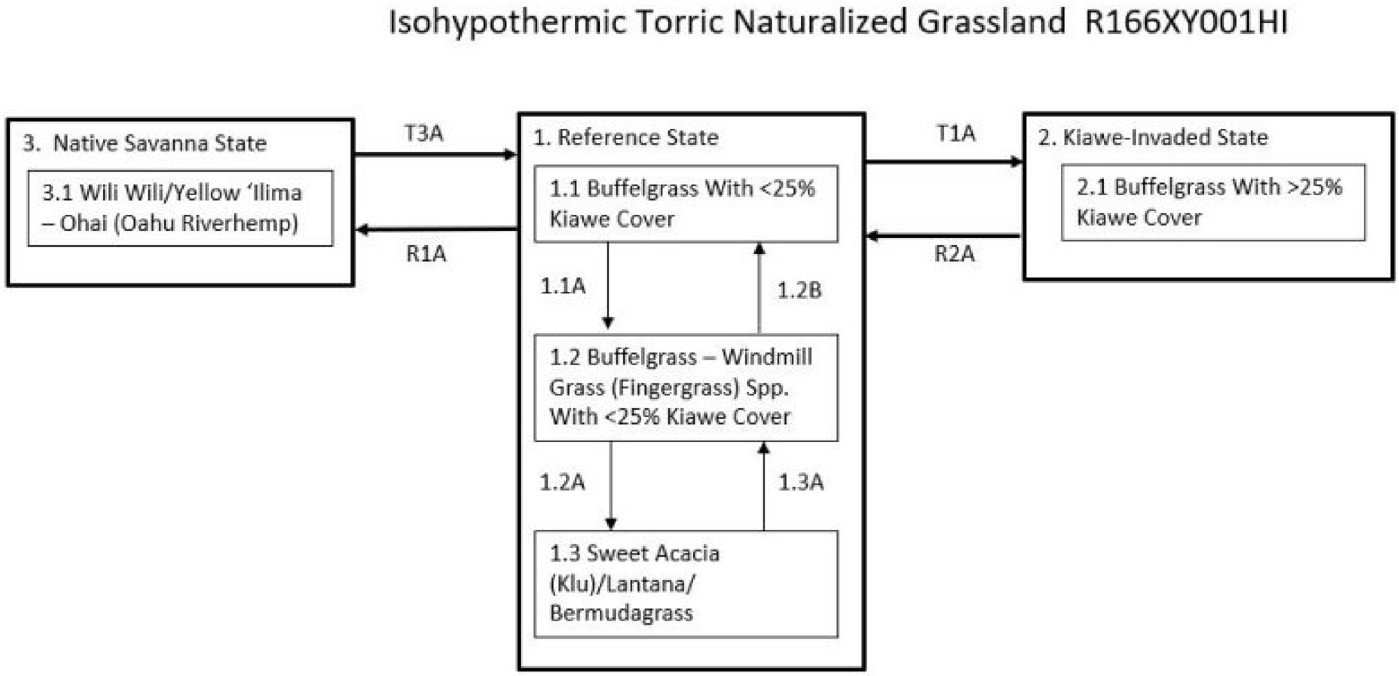

Figure 7. State-and-transition model diagram for the Isohyperthermic Torric Naturalized Grassland Ecological Site (R166XY001HI).

State 1
Reference State

This state consists of three community phases dominated by introduced grasses with less than 25 percent canopy cover of introduced trees. With lack of brush control or absence of wildfire, this state will transition to the Kiawe-Invaded State (2), in which production and cover of buffelgrass and other forages is reduced. Accumulation of fine fuels under light or no grazing pressure increases the risk of fire. This can produce an open grassland with little tree overstory but presents a fire threat to developed areas nearby and likelihood of eroded soil entering the nearby ocean. With continuous heavy grazing, particularly by cattle, buffelgrass will decrease. White leadtree or koa haole (*Leucaena leucocephala*) and anil de pasto or bush indigo (*Indigofera suffruticosa*) also will decrease under heavy grazing pressure. Increasers include windmill grass or fingergrasses (Chloris spp.), Bermudagrass (*Cynodon dactylon*), southern sandbur (*Cenchrus echinatus*), Egyptian grass (*Dactyloctenium aegyptium*), and Indian goosegrass (*Eleusine indica*), along with weedy forbs such as tropical whiteweed (*Ageratum conyzoides*), spiny amaranth (*Amaranthus spinosus*), hairy beggarticks or Spanish needle (*Bidens pilosa*), and lilac tasselflower (*Emilia sonchifolia*). With severe deterioration, shrubby species such as lantana (*Lantana camara*), rattlebox (Crotalaria spp.), and castorbean (*Ricinus communis*) increase. Native Florida hopbush or aalii (*Dodonaea viscosa*) can increase with exclusion of livestock grazing or lack of fire. The forage potential of the site is reduced by the increased canopy cover of this native shrub.

Community 1.1

Buffelgrass With <25% Kiawe Cover

Buffelgrass (*Pennisetum ciliare*) is the dominant forage species present. Kiawe (*Prosopis pallida*) and white leadtree or koa haole (*Leucaena leucocephala*) may be present. Kiawe is a potentially tall tree; its pods are of some forage value. If present at canopy cover greater than 25 percent, it can reduce production of grasses and forbs. Koa haole is a small tree that is browsed by livestock. Under continuous or excessively heavy grazing, this phase will change to phase 1.2 Buffelgrass-Windmill Grass (Fingergrass) Spp. With <25% Kiawe Cover. Buffelgrass comprises most of the productivity of this community phase. Other grass species that may be present are St. Augustine grass (*Stenotaphrum secundatum*), native tanglehead or piligrass (*Heteropogon contortus*) and kawelu (*Eragrostis variabilis*).

Dominant plant species

- kiawe (*Prosopis pallida*), tree
- buffelgrass (*Pennisetum ciliare*), grass

Community 1.2
Buffelgrass – Windmill Grass (Fingergrass) Spp. With <25% Kiawe Cover

This community phase consists of lower-value grass species such that become abundant upon continuous heavy grazing of buffelgrass. Further overgrazing exacerbates this process, causing a community change to phase 1.3. An overstory of kiawe (*Prosopis pallida*) may be present at up to 25 percent canopy cover. Windmill grass or fingergrasses (Chloris spp.) have increased in cover and production. Buffelgrass (*Pennisetum ciliare*) is much reduced. White leadtree or koa haole (*Leucaena leucocephala*) is much reduced compared with phase 1.1. Unpalatable species such as uhaloa (*Waltheria indica*), tropical whiteweed (*Ageratum conyzoides*), spiny amaranth (*Amaranthus spinosus*), and hairy beggarticks or Spanish needle (*Bidens pilosa*) have increased.

Dominant plant species

- kiawe (*Prosopis pallida*), tree
- buffelgrass (*Pennisetum ciliare*), grass
- windmill grass (*Chloris*), grass

Community 1.3
Sweet Acacia (Klu)/Lantana/Bermudagrass

This community phase consists mostly of grass species that are highly tolerant of grazing, particularly Bermudagrass (*Cynodon dactylon*), along with increased amounts of unpalatable shrubs, forbs, and subshrubs. White leadtree or koa haole is gone or is browsed down to stumps. Bare ground is extensive, so soil erosion by wind and water can be excessive. An overstory of kiawe (*Prosopis pallida*) may be present at up to 25 percent canopy cover. The most abundant grass species is Bermudagrass (*Cynodon dactylon*).

Sweet acacia or klu (*Acacia farnesiana*) and lantana (*Lantana camara*) are common, unpalatable shrubs which increase with disturbance. Some native Florida hopbush or aalii (*Dodonaea viscosa*), yellow 'ilima (*Sida fallax*), and uhaloa (*Waltheria indica*) typically are present.

Dominant plant species

- sweet acacia (*Acacia farnesiana*), tree
- lantana (*Lantana camara*), shrub
- Bermudagrass (*Cynodon dactylon*), grass

Pathway 1.1A
Community 1.1 to 1.2

Buffelgrass cover and vigor are reduced by continuous grazing, causing it to decrease and be partially replaced by less desirable forages.

Pathway 1.2B
Community 1.2 to 1.1

Phase 1.2 can change to phase 1.1 by application of a prescribed grazing program that allows buffelgrass to reassume dominance. Weed control may be necessary if taller weedy forbs or shrubs are abundant.

Pathway 1.2A
Community 1.2 to 1.3

Phase 1.2 changes to phase 1.3 with long-term or heavy continuous grazing. Species composition changes to dominance by shortgrasses, weedy forbs, and shrubs. Bare ground increases markedly.

Pathway 1.3A
Community 1.3 to 1.2

Phase 1.3 can change to phase 1.2 by application of a prescribed grazing program that allows buffelgrass to reassume dominance. Herbicidal weed control may be necessary.

State 2
Kiawe-Invaded State

The Kiawe Invaded State (2) consists of one community phase. It occurs when brush management has not been practiced or if fire has not occurred for a long time, allowing kiawe to increase in density and stature to a level at which understory production is significantly reduced.

Community 2.1
Buffelgrass With >25% Kiawe Cover

Kiawe (*Prosopis pallida*) canopy cover is 25 percent or higher. The understory consists of remnant buffelgrass (*Pennisetum ciliare*) and other grasses. This plant community is poor for livestock grazing due to reduced forage amounts beneath the dense tree canopy. Bare ground has increased, and there may be shallow, seasonal stream channels cut into the soil.

Dominant plant species

- kiawe (*Prosopis pallida*), tree
- buffelgrass (*Pennisetum ciliare*), grass

State 3
Native Savanna State

The Native Savanna State (3) consists of one historical community phase. Intact examples of this community no longer exist. This historical description is compiled from field observations of remnant vegetation, isolated plants on disturbed sites, a similar ecological site on the Island of Hawaii, and historical accounts of the islands before human influences disturbed these native plant communities.

Community 3.1
Wili Wili/Yellow 'Ilima – Ohai (Oahu Riverhemp)

This historical community phase is an open canopy of low to medium height (15 to 25 feet; 4.5 to 8 meters) trees, a shrub understory, and a ground layer of vines, herbs, and grasses. The species present would be typical of other low elevation dry Hawai'ian sites. Among the common tree species would be wili wili (*Erythrina sandwicensis*), ohe makai (*Reynoldsia sandwicensis*), lama (*Diospyros sandwicensis*), Hawai'i rockwort or kului (*Nototrichium sandwicense*), naio (*Myoporum sandwicense*), and alahe'e (*Psydrax odorata*). Some common shrubs would be Oahu Riverhemp or Ohai (*Sesbania tomentosa*), native caper or maiapilo (*Capparis sandwichiana*), alaweo or aheahea (*Chenopodium oahuense*), sandmat (Chamaesyce spp.), Hawai'ian cotton or mao (*Gossypium tomentosum*), coastal sandalwood or iliahi (*Santalum ellipticum*), Forida hopbush or aalii (*Dodonaea viscosa*), and yellow 'ilima (*Sida fallax*). Some common vines would be queen coralbead or huehue (*Cocculus orbiculatus*), kauna'oa or dodder (*Cuscuta sandwichiana*), oval-leaf clustervine or pauohiiaka (*Jacquemontia ovalifolia* ssp. sandwicensis), and oceanblue morning-glory or koali awa (*Ipomoea indica*). Native forb, grass, and grasslike species would be present.

Dominant plant species

- wili wili (*Erythrina sandwicensis*), tree
- yellow ‘ilima (*Sida fallax*), shrub

- Oahu riverhemp (*Sesbania tomentosa*), shrub

Transition T1A
State 1 to 2

The Reference State (1) transitions to the Kiawe-Invaded State (2) with lack of brush management practices or absence of wildfire.

Restoration pathway R1A
State 1 to 3

The Reference State (1) can be restored to a facsimile of the Native Savanna State (3). Domestic and feral ungulates and fire must be excluded from the site. Buffelgrass and other non-native vegetation must be eliminated, followed by plantings of native trees, shrubs, grasses, forbs, and vines. Supplemental irrigation may be necessary in the early stages of restoration.

Restoration pathway R2A
State 2 to 1

The Kiawe-Invaded State (2) can be restored to the Reference State (1) by applying brush management. Fire will kill kiawe; prescribed burning is typically not done in Hawaii due to the level of risk.

Transition T3A
State 3 to 1

The Native Savanna State (3) transitions to the Reference State (1) when cleared by fire, long-term ungulate disturbance, or mechanical means. Desired forage species are then re-established.

Additional community tables

Other references

References for R166XY001HI Isohyperthermic Torric Naturalized Grassland

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Definitions

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

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

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

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

Basal area or basal cover: The cross sectional area of the stem or stems of a plant or of all plants in a stand.

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.

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.

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.

Mollisols: Soils with relatively thick, dark surface horizons, high cation-exchange capacity, high calcium content, that do not become hard or very hard when dry. Mollisols are conducive to plant growth. They characteristically form under grass in climates that are seasonally dry but can form under forests.

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

Parent material: Unconsolidated and chemically weathered material from which a soil is developed.

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

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.

Torric soil moisture regime: See Aridic soil moisture regime.

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

Ustic soil moisture regime: A regime in which moisture is limited but present at a time when conditions are suitable for plant growth. In Hawaii it usually is associated with dry forests and subalpine shrublands.

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Rangeland health reference sheet

Interpreting Indicators of Rangeland Health is a qualitative assessment protocol used to determine ecosystem condition based on benchmark characteristics described in the Reference Sheet. A suite of 17 (or more) indicators are typically considered in an assessment. The ecological site(s) representative of an assessment location must be known prior to applying the protocol and must be verified based on soils and climate. Current plant community cannot be used to identify the ecological site.

Author(s)/participant(s)	
Contact for lead author	
Date	04/11/2026
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:**

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3. **Number and height of erosional pedestals or terracettes:**

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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:**

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):**

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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:**
