Ecological site VX157X01X004
Alluvial Woodland (Kiawe/Prosopis pallida)

Last updated: 6/11/2025
Accessed: 01/19/2026

General information

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

MLRA notes

Major Land Resource Area (MLRA): 157X–Arid and Semiarid Low Mountain Slopes

This MLRA occurs in the State of Hawaii on the islands of Hawaii and Maui. It consists primarily of moderately dissected, gently sloping to steep, leeward mountain slopes. Elevation ranges from sea level to about 6000 feet (0 to 1830 meters). Underlying geology is largely basaltic aa, which is covered by volcanic ash. Climate is dry tropical. Average annual precipitation typically ranges from 10 to 35 inches (255 to 890 millimeters), rising to 45 inches (1145 millimeters) on higher slopes, and mostly occurs from October through May. Much of the rainfall occurs in kona storms during winter. Average annual temperatures range from 55 to 76 degrees F (13 to 24 degrees C), with very little seasonal variation. Soils are mostly Andisols, Mollisols, and Aridisols with isohyperthermic or isothermic soil temperature regimes and ustic or aridic soil moisture regimes. Native vegetation is rare and consists of species characteristic of dry habitats, such as ilima, wiliwili, and aiea. Naturalized grasses such as buffelgrass and kikuyugrass and trees such as kiawe are common.

Classification relationships

This ecological site occurs within Major Land Resource Area (MLRA) 157 - Arid and Semiarid Low Mountain Slopes.

Ecological site concept

This ecological site is a dense woodland near sea level on the leeward slope of Mauna Kea on the island of Hawaii. Most of the site is at the village of Puako; a small part is next to the port at Kawaihae. Principal landowners are the State of Hawaii and some private holdings. It is easily accessed from Route 19 and then the local road to Puako.

The central concept of the Alluvial Woodland is of well drained, deep to very deep, sandy loam soil. The one soil series (one phase of this series) is an Andisol that formed in volcanic ash transported to the site by water over thousands of years. Average annual rainfall is 7 to 10 inches (175 to 250 millimeters). Annual air temperatures and rainfall create very warm (isohyperthermic), seasonally dry (torric) soil conditions. Elevations range from sea level (0 meters) to 50 feet (15 meters). Occasional, very brief flooding occurs, and it is assumed there is a brackish water table that is accessible to the very deep roots of kiawe trees. Because very little of the original native vegetation remains, the reference state of this ecological site consists of naturalized woodland vegetation. The dominant tree species is kiawe (*Prosopis pallida*), an introduced species. Where the tree canopy is open, the dominant grass species is introduced buffelgrass (*Pennisetum ciliare*).

Associated sites

VX157X01X003	**Rocky Volcanic Ash Savanna Kiawe/buffelgrass (Prosopis pallida/Pennisetum ciliare)** The Rocky Volcanic Ash Savanna occurs on the islands of Hawaii and Maui. It nearly surrounds the Alluvial Woodland. It receives higher average annual rainfall (7 to 20 versus 7 to 10 inches) and occurs at higher elevations (0 to 2200 versus 0 to 50 feet) than the Alluvial Woodland. Most importantly, it lacks the deep water table that produces the distinctive vegetation of the Alluvial Woodland.
VX161A01X001	**Isohyperthermic Desert** The Isohyperthermic Desert occurs only on the island of Hawaii. It shares the southwestern boundary off the Alluvial Woodland. These two ecological sites share soil temperature regimes (although the Isohyperthermic Desert has higher soil temperatures) and soil moisture regimes. The Isohyperthermic Desert receives higher average annual rainfall (7 to 20 versus 7 to 10 inces), and a higher elevation range (0 to 2000 versus 0 to 50 feet). Both have soils primarily formed in volcanic ash, but soils in the Isohyperthermic Desert range from shallow to moderately deep compared to very deep in the Alluvial Woodland. Most importantly, the Isohyperthermic Desert lacks the deep water table that produces the distinctive vegetation of the Alluvial Woodland.

Table 1. Dominant plant species

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

Legacy ID

R157XY004HI

Physiographic features

This ecological site primarily occurs on alluvial fans on sloping mountainsides of shield volcanoes. Flooding is occasional and very brief.

Table 2. Representative physiographic features

Landforms	(1) Shield volcano > Alluvial fan
Runoff class	Medium
Flooding duration	Very brief (4 to 48 hours)
Flooding frequency	Occasional
Ponding frequency	None
Elevation	0–15 m
Slope	0–6%
Water table depth	152–203 cm
Aspect	W

Climatic features

(Unless otherwise cited, the information in this section is derived from Western Regional Climate Center, cited 2020).

Summary for this ecological site

Average annual precipitation in this ecological site is 7 to 10 inches (175 to 250 millimeters). Most of the precipitation occurs from October through April. Average annual temperature is 72 degrees F (22 degrees C). Conditions 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. 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. Conditions are generally clear and sunny.

General principles

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

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

Hawaiian indigenous understanding recognized two seasons during the year: Kau or Kauwela (dry season) when the sun was directly overhead, days are long and warm and tradewinds are stronger and more consistent; Kau started on the first new moon in May when the Pleiades set at sunrise (Handy, 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 1991, Sanderson, 1993). These seasons are mostly consistent with modern observations today. These phenomena of pressure systems and seasonal differences interact with the islands' topography which together creates the various climate zones and patterns observed in the islands. One such general pattern can be seen in the differences in rainfall amounts between winter and summer; in low elevation dry areas the differences are greater whereas wetter areas exhibit less seasonal variation in rainfall.

Table 3. Representative climatic features

Frost-free period (characteristic range)	365 days
Freeze-free period (characteristic range)	365 days
Precipitation total (characteristic range)	279 mm
Frost-free period (actual range)	365 days
Freeze-free period (actual range)	365 days
Precipitation total (actual range)	279 mm
Frost-free period (average)	365 days
Freeze-free period (average)	365 days
Precipitation total (average)	279 mm

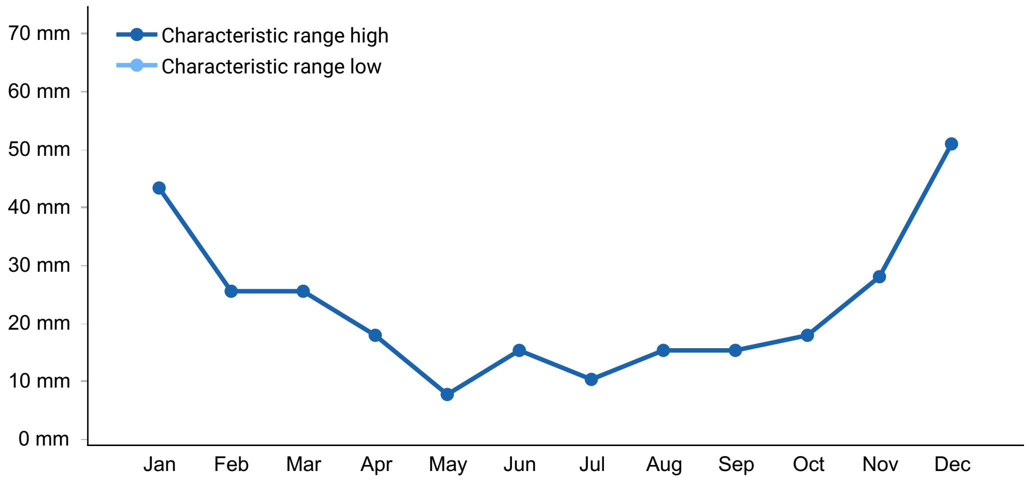


Figure 1. Monthly precipitation range

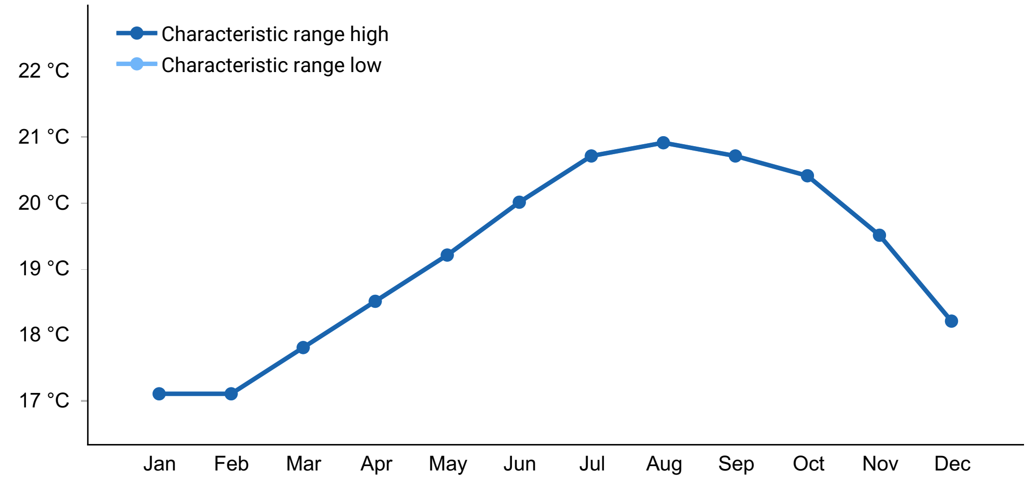


Figure 2. Monthly minimum temperature range

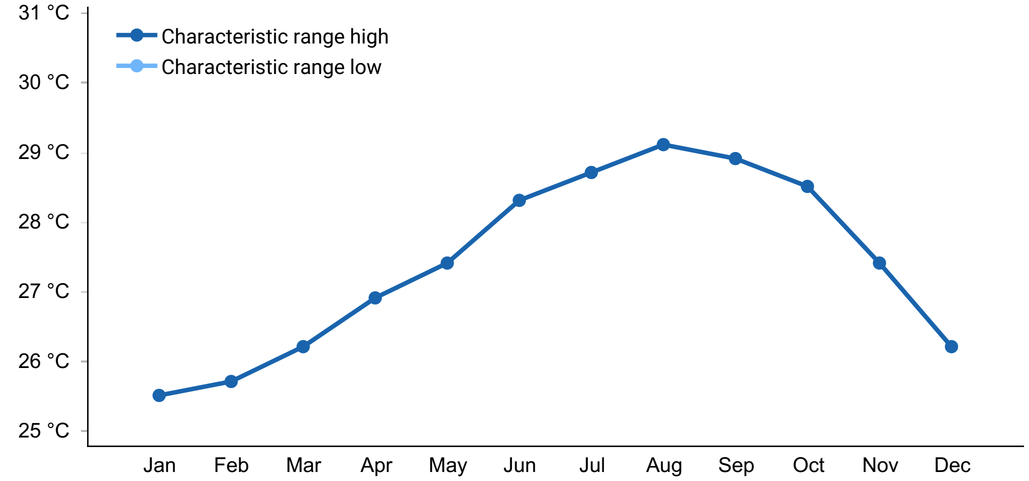


Figure 3. Monthly maximum temperature range

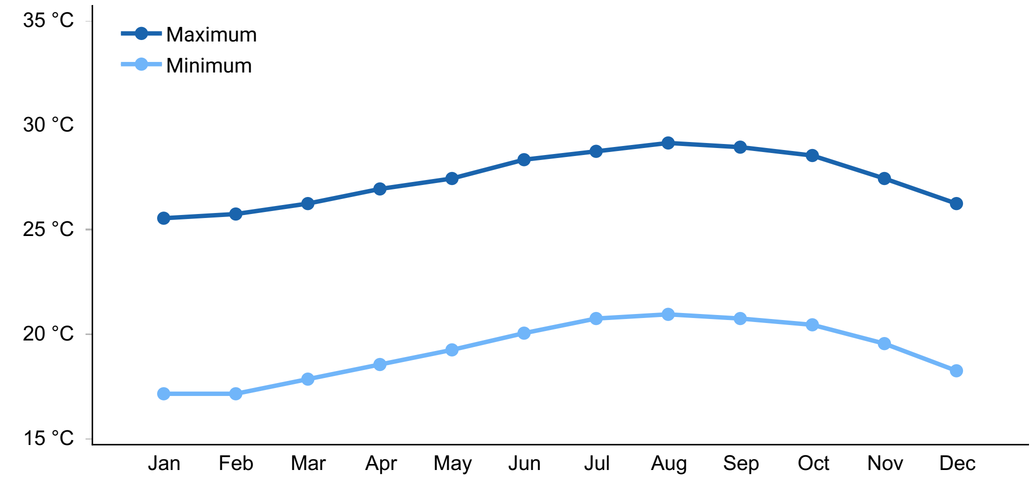


Figure 4. Monthly average minimum and maximum temperature

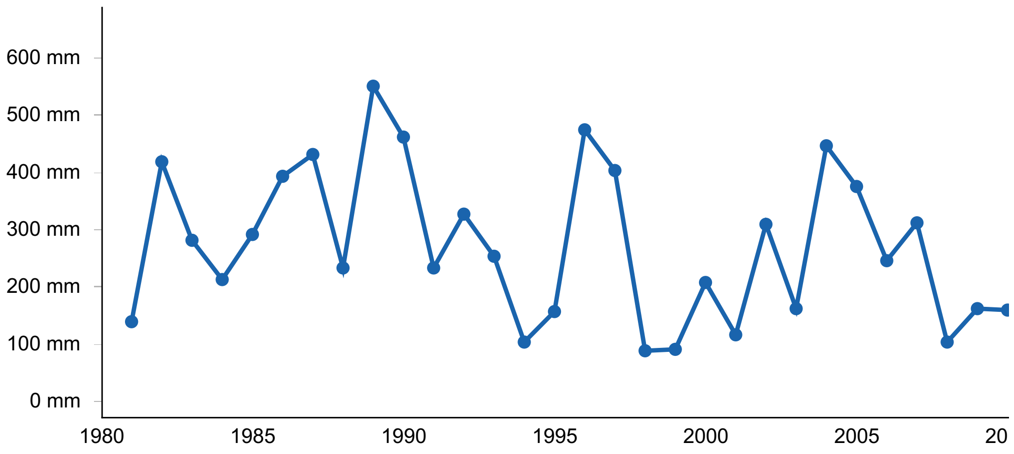


Figure 5. Annual precipitation pattern

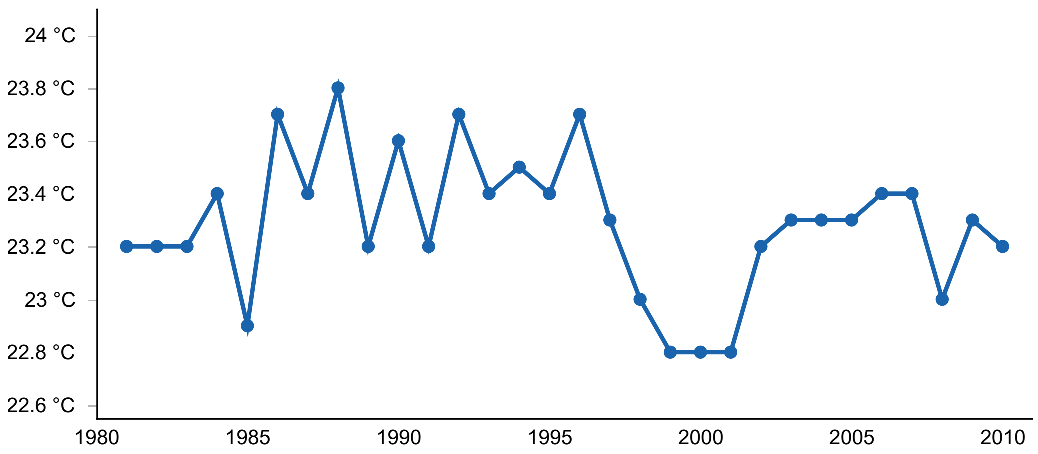


Figure 6. Annual average temperature pattern

Climate stations used

- (1) PUUKOHOLA HEIAU 98.1 [USC00518422], Kamuela, HI

Influencing water features

There are no water features.

Soil features

The soils in this ecological site consist of one phase of one series, Puako fine sandy loam, 0 to 6 percent slopes. These are mineral soils that formed in alluvium derived from volcanic ash and basic igneous rock.

The volcanic ash soils of the Hawaiian Islands 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).

Puako soils are classified as Torrands, or Andisols with a torric soil moisture regime. They are deep or very deep (40 to more than 60 inches or 100 to more than 150 centimeters) soils. They are deep to very deep (typically about 24 inches (60 centimeters) and are somewhat excessively drained due to their coarse textures (medial loamy sand to medial loam). They are deep to very deep (40 to >60 inches or 102 to >152 centimeters), and are well drained, typically having a medial fine sandy loam texture. Runoff is typically moderate due to hydrophobic conditions that can slow infiltration. Puako soils have mollic properties in their surface horizons. Some of characteristics of soils with mollic properties are a combination of a relatively thick, dark surface horizon (mollic epipedon) that does not become hard when dry, a dominance of calcium among the extractable cations, high (greater than 50 percent) base saturation, and a dominance of crystalline clay minerals of moderate or high cation-exchange capacity. Surface horizons have pH of about 5.3; extreme pH in subsurface horizons within 30 inches (75 centimeters) of the surface is 6.9. The soils have isohyperthermic (very warm) soil temperature regimes and torric soil moisture regimes (in normal years, dry for more than half of the growing season and moist for less than 90 consecutive days during the growing season).

This ecological site is assumed to have a brackish water table that is accessible to the roots of kiawe trees. This assumption is based on proximity to the ocean, the dominance of kiawe, and the know rooting and water quality tolerance characteristics of kiawe.

Table 4. Representative soil features

Parent material	(1) Alluvium–volcanic rock (2) Volcanic ash–volcanic rock
Surface texture	(1) Medial fine sandy loam
Drainage class	Well drained
Permeability class	Rapid
Depth to restrictive layer	102–152 cm
Soil depth	102–152 cm
Available water capacity (101.6-152.4cm)	40.13 cm
Electrical conductivity (101.6-152.4cm)	2–4 mmhos/cm
Sodium adsorption ratio (101.6-152.4cm)	45
Soil reaction (1:1 water) (101.6-152.4cm)	5.3
Subsurface fragment volume <=3" (Depth not specified)	Not specified
Subsurface fragment volume >3" (Depth not specified)	Not specified

Ecological dynamics

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

Natural Disturbances

There have been no lava flows or heavy volcanic ash flows on this ecological site that are recent enough to have affected the current vegetation and soils. It is possible that strong storms may sometimes cause minor windthrow of trees. Heavy rainfall can cause soil erosion and strong flows in gulches. Major storm events have also been known to trigger significant mud slides and flooding events. (Stearns 1942). Large earthquakes, such as the quake in 1938 may also cause geomorphically significant change to landscapes, although these are rare and impossible to predict.

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.

The first humans are believed to have migrated to Hawaii between 1000 and 1260 AD (Allen, 2014, Wilmhurst, 2011). Subsequent migrations and population growth 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 low lands 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). Lincoln et al (2018) notes that “at the inlet just south of the Kohala peninsula, two intensive hybrid systems that intermittently irrigated dryland areas existed.”

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).

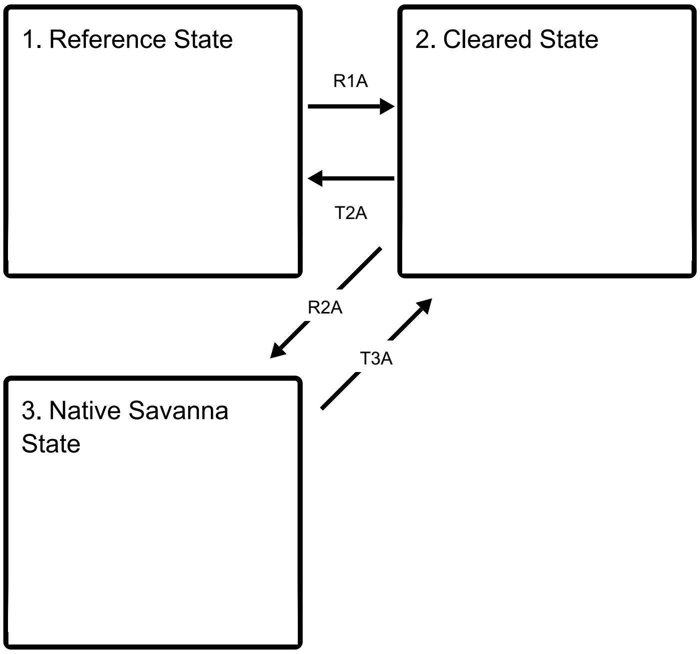
Through the 20th and into the 21st centuries, increases in human populations with attendant land development, as well as accelerated introduction of non-native mammals (including deer), birds, reptiles, amphibians, invertebrates, plants, and microorganisms, have brought about dramatic changes to wild ecosystems in Hawaii. Much of the original dry forest of this ecological site was cleared for intensive, irrigated production of sugarcane and pineapple. Few areas with native plant communities remain.

The original native vegetation probably was dry woodland or shrubland. Common native species, based on the current environment and remnant occurrences, would have been wiliwili (*Erythrina sandwicensis*), ohe makai (Polyscias sandwicensis), naio (*Myoporum sandwicense*), aalii (*Dodonaea viscosa*), ilima (*Sida fallax*), pauohiiaka or oval-leaf clustervine (Jacquemontia sandwicensis), and native grasses. Since the loss of the native dry forests and abandonment of modern agriculture, most of this ecological site has been utilized by livestock or developed for urban uses.

Wildfires caused by humans can burn the areas with open or no tree canopy where fine fuels may be adequate to carry a fire. The dense kiawe woodlands have very little understory vegetation. Feral ungulates graze and brows the vegetation to an extent. The most likely human disturbance is mechanical clearing of trees and other vegetation.

State and transition model

Ecosystem states



R1A - State 1 Reference can be restored to State 2 Cleared through disturbances such as fire, mechanical clearing, or herbicidal control of kiawe. Additional brush management strategies to avoid introduction of invasive shrubs (lantana, klu, koa-haole, etc) will be required. Once cleared, perennial grasses and forbs reassume dominance where they have regained access to soil moisture, nutrients and light. Fire: While fire will kill kiawe, the sparse grass and understory is not expected to carry fire that would result in stand replacement. Moreover, prescribed burning is typically not done in Hawaii due to the level of risk to relict native ecosystems and enjoined or embedded development. Mechanical Control: Some mechanical techniques that have been employed successfully include blade plowing, chain pulling, bulldozing, and stick raking (Gallaher and Merlin 2010). These methods can create high levels of ground disturbance and soil compaction. Herbicidal Control: Basal bark and cutstump application have been employed in Hawaii. Although this method works well for isolated individuals, it is both cost- and time-prohibitive for large areas with dense stands.

T2A - State 2 Cleared transitions to State 1 Reference in the absence of disturbance such as fire or land clearing activities.

R2A - State 2 Cleared may be restorable to a facsimile of State 3 Native Savanna. Measures (fencing, animal control) must be implemented to exclude all domestic and feral ungulates from the site. A firebreak must be created and maintained around the fence line if the site adjoins grasslands. Buffelgrass and other non-native vegetation must be killed, followed by plantings of native trees, shrubs, and vines. Supplemental irrigation will be necessary in the early stages of restoration.

T3A - State 3 Native Savanna transitions to State 2 Cleared when cleared by fire, long-term ungulate disturbance, herbicidal control, or by mechanical means. Once cleared, perennial grasses and forbs reassume dominance where they have regained access to soil moisture, nutrients and light. Fire: While fire will kill kiawe, the sparse grass and forb understory of the Native Savanna State would not be expected to carry fire that would result in stand replacement. Moreover, prescribed burning is typically not done in Hawaii due to the level of risk to other relict native ecosystems and enjoined or embedded development. Long-Term Systematic Herbivory: With continued, long-term systematic herbivory and browsing by goats, nearly all native grass and forbs (forages) and regenerating shrub and tree seedlings are removed allowing buffelgrass to resume dominance. Herbicidal Control: Basal bark and cutstump application have been employed to control trees in Hawaii. Although this method works well for isolated individuals, it is both cost- and time-prohibitive for large areas with dense stands. Mechanical Control: Some mechanical techniques to control unwanted trees and shrubs that have been employed successfully in Hawaii include blade plowing, chain pulling, bulldozing, and stick raking (Gallaher and Merlin 2010). These methods can create high levels of ground disturbance and soil compaction.

State 1 submodel, plant communities

1.1. Dense Kiawe Canopy with Sparse Understory (Prosopis pallida)

State 2 submodel, plant communities

2.1. Buffelgrass (Pennisetum ciliare)

State 3 submodel, plant communities

3.1. Wiliwili/torrid panicgrass (Erythrina sandwicensis/Panicum torridum)

State 1
Reference State

Figure 7. State 1 Reference. Puako fine sandy loam, 0 to 3 percent map unit. The dense band of Kiawe characteristic of the Alluvial Woodland is visible on the horizon. Elevation ~ 50 feet. Average annual rainfall 7 to 10 inches. John Proctor. July 21, 2021.

This state consists of one community phase. It occurs when the area has not been cleared mechanically and if wildfire has not occurred for a long time, allowing kiawe to increase in density and stature to a level at which understory vegetation becomes sparse. The dense kiawe woodlands have very little understory vegetation. While the presence of burnable fuels is low, it is conceivable that fire could carry through the sparse understory and litter layer to some extent. As such, State 1 Reference is likely to maintain itself unless cleared mechanically.

Community 1.1
Dense Kiawe Canopy with Sparse Understory (Prosopis pallida)

Kiawe canopy cover is 60 percent or higher. Trees are 25 to 30 feet (7.5 to 9 meters) tall. The understory consists of scattered grasses, forbs, and shrubs. Presence of burnable fuels is low, but it is conceivable that fire could carry through the sparse understory and litter layer to some extent.

State 2
Cleared State

Figure 8. State 2 Cleared. Puako fine sandy loam, 0 to 3 percent slopes map unit. This clearing is a fire break designed to protect adjacent development. Elevation ~ 50 feet. Average annual rainfall 7 to 10 inches. John Proctor. July 21, 2021.

This state consists of one community phase dominated by introduced grasses. Tree canopy cover varies from 0 to about 60 percent. In the absence of clearing activities or wildfire, this state will transition to State 1 Reference, in which tree cover increases and production and cover of grass, forbs, and shrubs is reduced. Gradual accumulation of fine fuels increases the possibility of wildfire. This can maintain 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.

Community 2.1
Buffelgrass (Pennisetum ciliare)

Buffelgrass is the dominant grass species. Kiawe (*Prosopis pallida*) is present in varying density and stature. Other species, almost all introduced, are present in small amount. These may include pitted beardgrass (*Bothriochloa pertusa*), swollen fingergrass (*Chloris barbata*), Bermudagrass (*Cynodon dactylon*), and hooked bristlegrass (*Setaria verticillata*). The shrub lantana (*Lantana camara*) may be present along with klu or sweet acacia (*Vachellia farnesiana*). Some possible forbs are golden crownbeard (*Verbesina encelioides*), lion's ear (*Leonotis leonurus*), and Australian saltbush (*Atriplex semibaccata*). The small native shrub uhaloa (*Waltheria indica*) may be encountered.

Dominant plant species

- buffelgrass (*Pennisetum ciliare*), grass

State 3
Native Savanna State

Figure 9. State 3. Native Savanna State. This image of a native Wiliwili (Erythrina sandwicensis) tree from the Waikoloa Dry Forest Initiative serves as a theoretical representation of the Native Savanna State

This state consists of one community phase. Intact examples of this community no longer exist. This description is compiled from field observations of remnant plants, environmental ranges of native species that plausibly could occur, and observations on other ecological sites. Species are those that can grow near the ocean in very dry, warm conditions. They probably grew as an open savanna.

Community 3.1
Wiliwili/torrid panicgrass (Erythrina sandwicensis/Panicum torridum)

The hypothetical appearance of this 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. Wiliwili (*Erythrina sandwicensis*) is the most likely tree species. Some possible shrubs include alena (*Boerhavia herbstii*), red spiderling (*B. acutifolia*), aheahea (*Chenopodium oahuense*), and beach sandmat (Euphorbia degeneri). Native forbs, vines, and grasses are also likely species to have occurred here. Please see the accompanying species list.

Restoration pathway R1A
State 1 to 2

Reference State

Cleared State

State 1 Reference can be restored to State 2 Cleared through disturbances such as fire, mechanical clearing, or herbicidal control of kiawe. Additional brush management strategies to avoid introduction of invasive shrubs (lantana, klu, koa-haole, etc) will be required. Once cleared, perennial grasses and forbs reassume dominance where they have regained access to soil moisture, nutrients and light. Fire: While fire will kill kiawe, the sparse grass and understory is not expected to carry fire that would result in stand replacement. Mechanical Control: Some mechanical techniques that have been employed successfully include blade plowing, chain pulling, bulldozing, and stick raking (Gallaher and Merlin 2010). These methods can create high levels of ground disturbance and soil compaction. Herbicidal Control: Basal bark and cutstump application have been employed in Hawaii. Although this method works well for isolated individuals, it is both cost- and time-prohibitive for large areas with dense stands.

Conservation practices

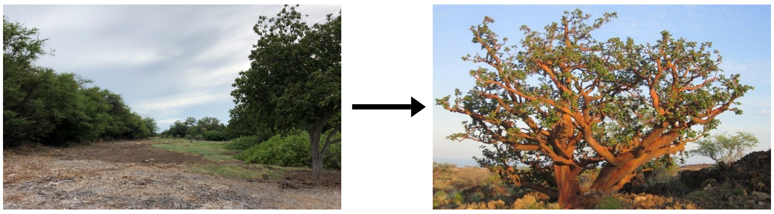
Brush Management
Land Clearing

Restoration pathway T2A
State 2 to 1

Cleared State Reference State

State 2 Cleared transitions to State 1 Reference in the absence of disturbance such as fire or land clearing activities.

Restoration pathway R2A
State 2 to 3



Cleared State Native Savanna State

State 2 Cleared may be restorable to a facsimile of State 3 Native Savanna. Measures (fencing, animal control) must be implemented to exclude all domestic and feral ungulates from the site. A firebreak must be created and maintained around the fence line if the site adjoins grasslands. Buffelgrass and other non-native vegetation must be killed, followed by plantings of native trees, shrubs, and vines. Supplemental irrigation will be necessary in the early stages of restoration.

Conservation practices

Fence
Firebreak
Integrated Pest Management (IPM)
Restoration and Management of Rare and Declining Habitats
Native Plant Community Restoration and Management
Invasive Plant Species Control

Transition T3A
State 3 to 2

Native Savanna State

Cleared State

State 3 Native Savanna transitions to State 2 Cleared when cleared by fire, long-term ungulate disturbance, herbicidal control, or by mechanical means. Once cleared, perennial grasses and forbs reassume dominance where they have regained access to soil moisture, nutrients and light. Fire: While fire will kill kiawe, the sparse grass and forb understory of the Native Savanna State would not be expected to carry fire that would result in stand replacement. Long-Term Systematic Herbivory: With continued, long-term systematic herbivory and browsing by goats, nearly all native grass and forbs (forages) and regenerating shrub and tree seedlings are removed allowing buffelgrass to resume dominance. Herbicidal Control: Basal bark and cutstump application have been employed to control trees in Hawaii. Although this method works well for isolated individuals, it is both cost- and time-prohibitive for large areas with dense stands. Mechanical Control: Some mechanical techniques to control unwanted trees and shrubs that have been employed successfully in Hawaii include blade plowing, chain pulling, bulldozing, and stick raking (Gallaher and Merlin 2010). These methods can create high levels of ground disturbance and soil compaction.

Conservation practices

Brush Management
Land Clearing

Additional community tables

Other references

Other Information

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.

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

Aquisalids: These are salty soils in wet areas. Although wet, the dissolved salts make the soils physiologically dry (the chemical activity, or effective concentration, of water is low). Aquisalids typically support plant species that are adapted to these conditions.

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.

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

Ashy: A “soil texture modifier” for volcanic ash soils having a water content at the crop wilting point of less than 30 percent; a soil that holds relatively less water than “medial” and “hydrous” soils.

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.

Blue rock: The dense, hard, massive lava that forms the inner core of an aa lava flow.

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.

$CaCO_3$ equivalent: The amount of free lime in a soil. Free lime exists as solid material and typically occurs in regions with a dry climate.

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

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

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

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

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

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

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

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

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

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.

Kipuka: An area of land surrounded by younger (more recent) lava. Soils and plant communities within a kipuka are older than, and often quite different from, those on the surrounding surfaces.

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.

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.

Oxisols: Soils characteristic of humid, tropical or subtropical regions that formed on land surfaces that have been stable for a long time. In Hawaii, they typically occur on islands or parts of islands that have been volcanically inactive for a long time. Oxisols are highly weathered, consist largely of quartz, kaolin clays, and aluminum oxides, and have low ion exchange capacity and loamy or clayey texture.

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.

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

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

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

Psamments: Sandy soils that have low water-holding capacity, are susceptible to wind erosion, and typically have ground water deeper than 20 inches (50 centimeters).

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

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

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

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

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

Soil moisture regime: A term referring to the presence or absence either of ground water or of water held at a tension of less than 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.

Spodosols: Soils with a spodic B horizon that has an accumulation of black or reddish amorphous materials that have a high pH-dependent ion exchange capacity, coarse texture, and few base cations. Above the spodic horizon there often is a light-colored albic horizon that was the source of the amorphous materials in the spodic horizon.

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.

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.

Ultisols: Soils that have been intensively leached and weathered. They have a B horizon that has accumulated clay that has translocated there from higher horizons. They have moderate to low cation exchange capacity and low base saturation. The highest base saturation normally is in the few centimeters directly beneath the surface due to cycling of bases by plants.

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	06/11/2025
Approved by	Jamin Johanson
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:**

4. **Bare ground from Ecological Site Description or other studies (rock, litter, lichen, moss, plant canopy are not bare ground):**

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

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

7. **Amount of litter movement (describe size and distance expected to travel):**

8. **Soil surface (top few mm) resistance to erosion (stability values are averages - most sites will show a range of values):**

9. **Soil surface structure and SOM content (include type of structure and A-horizon color and thickness):**

10. **Effect of community phase composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:**

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

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

    Dominant:

Sub-dominant:

Other:

Additional:

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

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

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

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

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17. **Perennial plant reproductive capability:**
