Ecological site VX161B01X501
Kona Weather Ustic Forest

Accessed: 05/19/2024

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): 161B–Semiarid and Subhumid Organic Soils on Lava Flows

This MLRA occurs in the State of Hawaii in the Districts North and South Kona on the Big Island of Hawaii. This area is the leeward (western) side of the island on the slopes of Mauna Loa and Hualalai volcanoes. Elevation ranges from sea level to 6000 feet (about 2000 meters). Slopes follow the undulating to very steep topography of the lava flows. The flows are basaltic aa or pahoehoe lava, which are covered by a very shallow layer of organic material mixed with varying amounts of volcanic ash, although some places are covered only by volcanic ash. Climate ranges from dry to moist tropical. Average annual precipitation typically ranges from 30 to 80 inches (750 to 2000 millimeters), increasing with elevation. Rainfall occurs mostly in spring and summer. At higher elevations, frequent afternoon fog accumulation ameliorates evaporation and may add fog drip to the soil. Average annual air temperatures range from 55 to 75 degrees F (12 to 24 degrees C), with little seasonal variation. Dominant soils are Histosols and Andisols with isomesic to isohyperthermic soil temperature regimes. Very young lava flows may have no soil covering. Native vegetation changes as rainfall and fog increase with elevation. In the driest areas near sea level, sparse, low stature shrubs, grasses, and forbs predominate. Vegetation stature and density gradually increase with elevation to typical dry forest species such as lama, wiliwili, and alahee, transitional forest with olopua and papala kepau, rain forest with ohia lehua, koa, and hapuu, cool dry forest with koa, mamani, and mountain sandalwood, and finally cool dry shrublands that extend up to the highest unvegetated lava flows.

Classification relationships

This ecological site occurs within Major Land Resource Area (MLRA) 161B - Semiarid and Subhumid Organic Soils on Lava Flows.

Ecological site concept

This ecological site is the "dry forest" that begins in the north on the lower slopes of Hualalai, mauka of Kona International Airport and between the upper (Rte. 190) and lower (Rte. 19) highways, then runs southward from Kailua-Kona between the coast and the main highway (Rte. 11), and then straddles Route 11 (mauka of the coast) from near Milolii southward around South Point and then northward to near Pahala. Good examples can be seen in Manuka State Park and along the gravel road from Manuka toward the coast. Almost all the wild vegetation growing near public roads is dominated by introduced plant species. The coffee-growing areas makai of Highway 11 are in this ecological site.

The central concept of the Kona Weather Ustic Forest is well to excessively drained, shallow to deep soils formed in deposits of highly decomposed plant material or volcanic ash, either of which may be found over pahoehoe (flat lava flows) or within the spaces of aa (cobbly lava flows). Lava flows range from 750 to 10,000 years old. Annual air temperatures and rainfall create hot to warm (isohyperthermic to isothermic), seasonally dry (ustic) soil conditions. Most of this ecological site has a Kona weather pattern in which most of the rainfall occurs during March through June, with Kona storms providing some additional rainfall during the winter months. These soils and this weather pattern support a dry tropical forest with high species diversity. The low to medium stature (25 to 70 feet; 8 to 22 meters) upper canopy is dominated by ohia lehua (*Metrosideros polymorpha*) on younger lava flows and by lama

(*Diospyros sandwicensis*) on older lava flows. The lower levels of the plant community contain many small tree, shrub, vine, fern, grass, and sedge species. Where this ecological site grades into rain forest at higher elevations there can be found in places a distinctive plant community characterized by olopua (*Nestegis sandwicensis*), papala kepau (*Pisonia brunoniana*), hame (*Antidesma pulvinatum*), and aiea (*Nothocestrum breviflorum*).

Associated sites

VX160X01X504	**Ustic-Dry Udic Forest** F160XY504 Ustic-Dry Udic Forest is a higher elevation, moderately dry ecological site adjoining F161BY501 in the mauka part of Kahuku Ranch (HVNP). F160XY504 has an overstory dominated by koa and ohia lehua.
VX161B01X502	**Kona Weather Udic Forest** F161BY502 Kona Weather Udic Forest borders F161BY501 at higher elevations. The two ecological sites share similar parent materials and underlying lava types, but F161BY502 is cooler and moister, and supports rain forest vegetation. The transitional zone between the two ecological sites still exists in some areas; it is dominated by olopua trees.

Similar sites

VX161B01X500	**Ustic Isothermic Forest** F161BY500 Ustic Isothermic Forest borders on 161BY501 to the north. Both ecological sites are tropical dry forest, but F161BY500 is generally at higher elevations and has a different rainfall pattern. They share many plant species in common, but the proportions of those species are often different.
VX162X01X501	**Dry Isohyperthermic Forest** F162XY501 Ustic/Dry Udic Isohyperthermic Forest is on the southeast Puna District coastal strip at low elevations. F162XY501 has higher rainfall and higher temperatures and evaporation than F161BY501. Both ecological sites share many species in common, but F162XY501 has much more abundant pandanus trees and apparently lower species diversity and tree statures.

Table 1. Dominant plant species

Tree	(1) *Diospyros sandwicensis* (2) *Psydrax odorata*
Shrub	Not specified
Herbaceous	Not specified

Legacy ID

F161BY501HI

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 (2) Lava flow
Flooding duration	Very brief (4 to 48 hours)
Flooding frequency	None to occasional
Ponding frequency	None
Elevation	15–762 m
Slope	2–70%
Water table depth	152 cm

Aspect	SE, S, W

Climatic features

Average annual precipitation ranges from 30 to 60 inches (750 to 1500 millimeters). On west facing slopes (North and South Kona Districts), most precipitation falls from late summer through autumn. Going around the southern tip of the island to south and southeast facing slopes, the precipitation maximum shifts to winter. Average annual temperature ranges from 68 to 74 degrees F (20 to 23 degrees C) with very little seasonal variation.

Air temperature in Hawaii 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).

Hawaii lies 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 6000 feet (very roughly 2000 meters). As the trade winds from the northeast are forced up the mountains of the island their moisture condenses, creating rain on the windward slopes; the leeward side of the island receives little of this moisture.

On the leeward side of the island, particularly in the Kona area, a "Kona weather pattern" exists. Heating of the land during the day pulls moist ocean air up the mountain slopes that produces clouds and rain in the afternoon. A cool breeze moves down the slopes at night. This weather pattern is strongest during the summer, creating rainfall in that season.

In winter, low pressure systems often approach the island from the west, producing extensive rainstorms that primarily affect the leeward sides of the island.

Reference: Giambelluca and Schroeder 1998.

Table 3. Representative climatic features

Frost-free period (average)	365 days
Freeze-free period (average)	365 days
Precipitation total (average)	940 mm

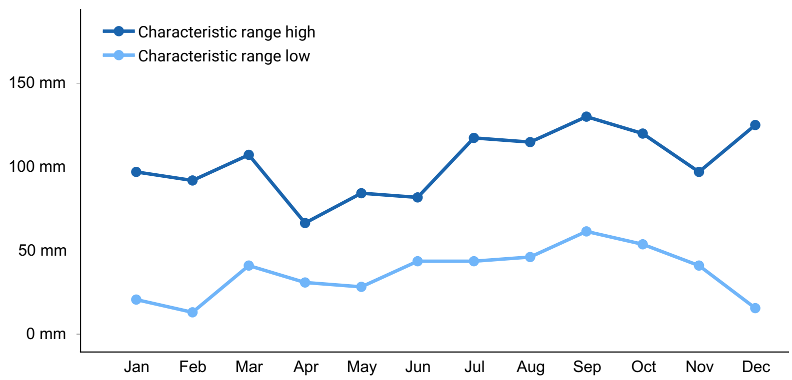

Figure 1. Monthly precipitation range

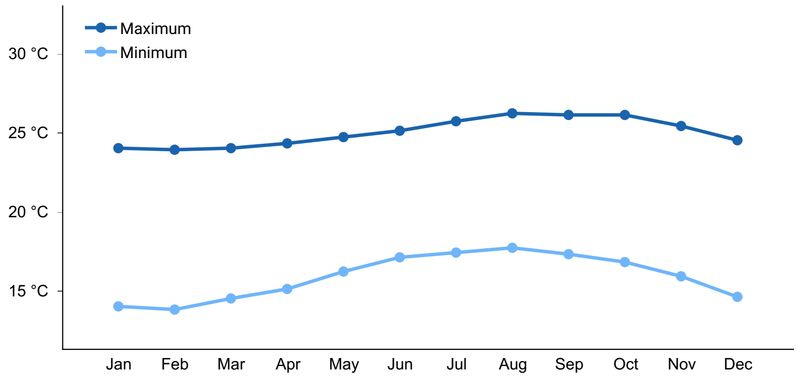

Figure 2. Monthly average minimum and maximum temperature

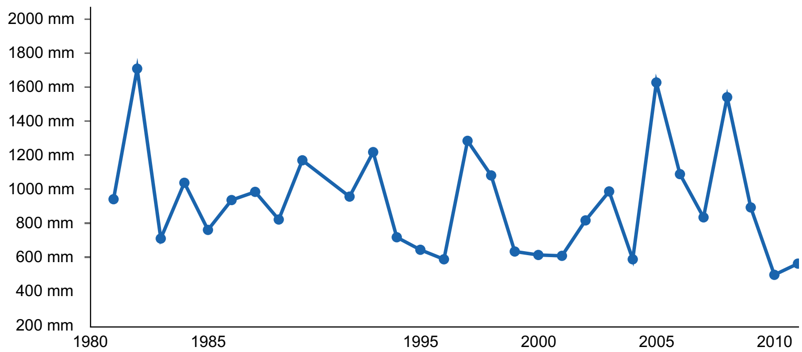

Figure 3. Annual precipitation pattern

Climate stations used

- (1) OPIHIHALE NO 2 24.1 [USC00517166], Captain Cook, HI

Influencing water features

Shallow gulches with solid lava bottoms can carry flash floods after periods of high rainfall. In limited areas, very shallow soils over pahoehoe that are complexed with rock outcrops and are on steep slopes can undergo brief, shallow flooding under high rainfall.

Soil features

Typical soils are of three types: highly decomposed plant materials, either moderately deep in aa or shallow over pahoehoe; very shallow to shallow medial silt loams and medial sandy loams formed in rapidly weathered volcanic ash deposited over pahoehoe; and moderately deep to deep silt loams and silty clay loams formed in rapidly weathered volcanic ash deposited over aa or pahoehoe. Soils under lama forest canopies often have a distinctive brown organic surface layer formed in leaf litter. Runoff potential ranges from negligible on aa to very high on pahoehoe. Soil reaction (pH) ranges from strongly acid to neutral in surface horizons and strongly acid to neutral in deeper subsurface layers. Soil temperature regimes range from isohyperthermic at low elevation to isothermic at higher elevations. Soil moisture regimes are ustic (in most years, dry for more than 90 cumulative days but less than 180 days).

The volcanic ash soils of the Island 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 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).

Andisols formed on pahoehoe lava can be very shallow to very deep. Pahoehoe is referred to as a “lithic contact,” which is a boundary between soil and underlying material that is coherent, continuous, difficult to dig with a spade, and contains few cracks that can be penetrated by roots (Soil Survey Staff 1999). Pahoehoe is typically very limiting to root penetration due to the spacing and size of cracks. However, this characteristic of pahoehoe is variable, and there are many instances of stands of large trees growing on very shallow and shallow ash soils over pahoehoe.

The lava rock fragments that constitute aa range in size from gravel (2 mm to 76 mm, or up to 3 inches) to stones (250 mm to 600 mm, or 10 to 25 inches), but are primarily gravel and cobbles (76 mm to 250 mm, or 3 to 10 inches). Below the layer of rock fragments is massive lava called “bluerock.” The interstices between rock fragments of Andisols formed in aa are filled with soil from the surface to the blue rock at the bottom of the soil. Some Andisols in aa have few or no rock fragments in the upper horizons, while others may have large amounts of rock fragments in all horizons and on the soil surface.

Soils that are moderately deep (20 to 40 inches, or 50 to 100 cm) or deeper over underlying lava appear to present few or no limits on native, pasture, or weedy vegetation, and it seems to make no difference whether the lava rock is pahoehoe or aa. However, these soils may present some tillage difficulties when formed in aa and containing significant amounts of coarse rock fragments near the surface. Very shallow and shallow ash soils over pahoehoe are sometimes ripped to break up the underlying lava and create a deeper rooting zone.

The organic soils of the Island of Hawaii are classified as Histosols. They were formed mainly in organic material consisting of highly decomposed leaves, twigs, and wood with small amounts of basic volcanic ash, cinders, and weathered lava; this is called highly decomposed parent material. Some of these soils contain slightly or moderately decomposed parent material, especially at or near the soil surface.

Unlike many organic soils such as peat or muck that form in long-term water-saturated conditions, these organic soils form by accumulation and transformation of litter on dry surfaces of lava rock or in gaps between lava rocks. These organic soils are referred to as litter or an O horizon.

All of the Histosols on the Big Island are classified as “euic,” which means they have relatively high base saturation as indicated by a pH of 4.5 or higher; most Big Island Histosols have pH well above this minimum.

Histosols on pahoehoe lava tend to be shallow (less than 20 inches or 50 centimeters) or very shallow (less than 10 inches or 25 centimeters). Pahoehoe is referred to as a “lithic contact,” which is a boundary between soil and underlying material that is coherent, continuous, difficult to dig with a spade, and contains few cracks that can be penetrated by roots (Soil Survey Staff 1999). Pahoehoe is typically very limiting to root penetration due to the spacing and size of cracks. However, this characteristic of pahoehoe is variable, and there are many instances of large trees growing on very shallow and shallow soils over pahoehoe. When depth of soil to pahoehoe is less than 18 cm (7.2 inches), the soil is referred to as “micro.”

The lava rock fragments that constitute aa range in size from gravel (2 mm to 76 mm, or up to 3 inches) to stones (250 mm to 600 mm, or 10 to 25 inches), but are primarily gravel and cobbles (76 mm to 250 mm, or 3 to 10 inches). Below the layer of rock fragments is massive lava called “bluerock.” The interstices between rock fragments of Histosols formed in aa are filled with soil material from the surface to a particular depth, often moderately deep (20 to 40 inches, or 50 to 100 centimeters), but sometimes shallower or deeper depending on the soil series. Between this soil material-filled horizon and the bluerock the interstices contain little or no soil material. However, live roots are often present in this horizon. These soils often support dense forests with large trees despite their unusual conformation. In order to observe the natural state of the soil, one must carefully disassemble the lava rock fragments so as not to allow the soil materials to fall into the gaps below.

Ripping and crushing lava by heavy machinery transforms these organic soils into Arents, which basically means sandy (the “Ar” or arenic; think of a sandy arena) soils with little or no natural horizon development (the “ents” or Entisols). Ripping pahoehoe lava eliminates the root-limiting layer of the lava. Crushing of ripped pahoehoe fragments or aa reduces the size of the fragments and the gaps between them and creates some finer, sand-sized particles. As much as 50% of the original organic matter can be lost in this process due to oxidation, but the resulting Arents are more suitable for agricultural operations. Arents are very susceptible to weed invasion, but there have been apparently successful attempts at restoration of native plant species.

Figure 5. Kaimu soil (an organic soil)

Table 4. Representative soil features

Parent material	(1) Organic material–basalt (2) Basaltic volcanic ash–aa lava
Surface texture	(1) Medial silt loam (2) Ashy sandy loam (3) Silty clay loam
Family particle size	(1) Loamy
Drainage class	Well drained to excessively drained
Permeability class	Rapid
Soil depth	5–152 cm
Surface fragment cover <=3"	0–40%
Surface fragment cover >3"	0–40%
Available water capacity (0-101.6cm)	2.54–20.32 cm
Calcium carbonate equivalent (0-101.6cm)	0%
Electrical conductivity (0-101.6cm)	0–2 mmhos/cm
Sodium adsorption ratio (0-101.6cm)	0
Soil reaction (1:1 water) (0-101.6cm)	5.6–7.3
Subsurface fragment volume <=3" (Depth not specified)	0–75%
Subsurface fragment volume >3" (Depth not specified)	0–75%

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.

States and community phases within this ecological site were differentiated by inspection of data; ordination programs were not available. They were verified by professional consensus and consistent examples in the field.

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. Flows on this ecological site range from 750 to 10,000 years old, with most of the flows being in the younger part of this age spectrum. This is a sufficient length of time for development of soils that support the typical vegetation, although the youngest flows in drier parts of the ecological site will have less developed soils and vegetation than other areas. Younger, still unvegetated flows have cut across this ecological site and may do so again. To some extent, lava flows may start wildfires, but this is not a frequent occurrence. Wildfires 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 rapidly recovers 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. 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 to the typical range for this ecological site.

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). Much of this ecological site occurs at elevations below 1500 feet and in areas that supported high human populations and intensive agriculture. Areas that were inhabited in prehistoric times often still contain stonework artifacts and plants introduced by the Polynesians, particularly kukui trees (Aleurites moluccana).

Kona and Kau were the main population areas on Hawaii. There was much cultivation in the Manuka area, and Hawaiians had cleared much of Kau before European discovery. Lands were mostly developed where there was good fishing in the ocean nearby, which partly explains why Kona and Kau had the biggest agricultural developments (Craighill and Handy 1991).

Endemic flora of plains were slowly eliminated from areas capable of cultivation. Patches of wilderness remained only in rocky places and some kipuka, although kipuka were utilized if they were moist and accessible. This forest zone was profoundly modified by use by Hawaiians through clearing and use of forest trees. Koa, ohia lehua, kauila, mamaki, wiliwili, hapuu, olopua, and other species were utilized (Craighill and Handy 1991).

Taro was planted between about 1000 to 3000 feet (300 to 925 meters) elevation; gourds, sweet potato, breadfruit, yams, bananas, and other crops were grown in elevation zones appropriate to their moisture requirements. Evidence of former cultivation in the form of wild crop plants is seen in current ohia forests that are now over 100 years old (Craighill and Handy 1991).

Archaeological studies from the Kona Field System illustrate the expansion of organized Hawaiian agriculture starting as early as the year 1300 AD, and certainly by the late 1400s. The Kona Field System is a vast area on the slopes between Kailua and Honaunau (Clark 1983).

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.

This ecological site evolved without the presence of large mammals. 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). Today, some of this ecological site is utilized for cattle ranching.

Through the 20th and into the 21st centuries, increases in human populations with attendant urban 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.

Coffee plantations are widespread in this ecological site. Macadamia nut orchards are also common. These crops occupy many of the deeper ash soils especially, as well as areas that were described by Rock (1913) as being the most diverse natural forests in this ecological site. Sugar plantations, now abandoned, formerly occupied the deep ash soils in Kau; these lands now are naturalized grasslands dominated by guineagrass (*Urochloa maxima*).

Crimson fountaingrass (*Pennisetum setaceum*) has recently invaded this ecological site and is increasing. Fountaingrass is well adapted to this environment. Stands of this species are extremely susceptible to intense wildfires that eliminate most other vegetation.

State and transition model

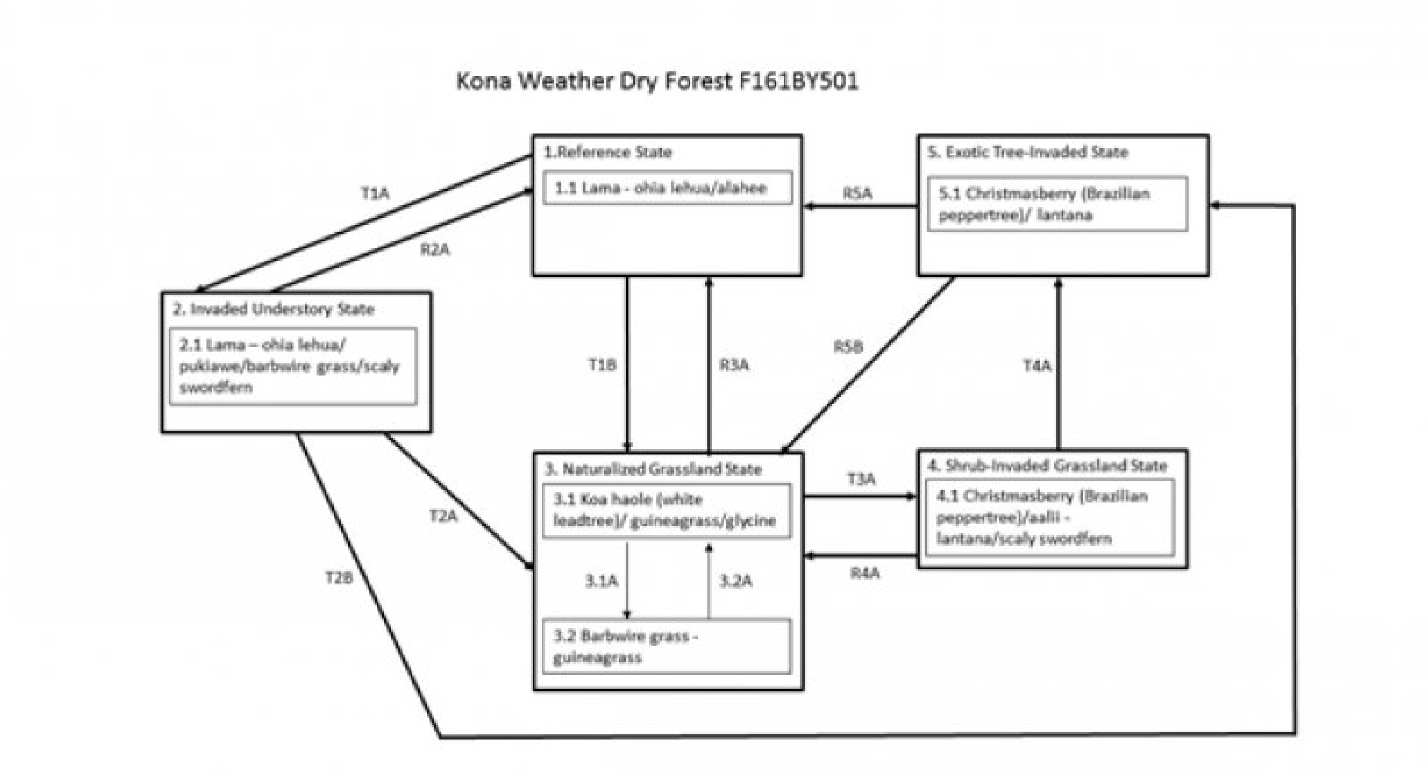

Figure 6. STM F161BY501

State 1
Reference State

This state consists of one community phase. The general appearance of this ecological site is an open to nearly closed canopy of medium to tall height to 40 feet (12 meters) when dominated by lama (*Diospyros sandwicensis*) or to 70 feet (22 meters) when dominated by ohia lehua, an understory of shrubs and small trees, and a ground layer of vines, forbs, and grasses. Lama-dominated stands have standing live timber of 400-1500 cubic feet per acre; stands dominated by ohia lehua range from 400-2300 cubic feet per acre. The canopy becomes shorter and sparser where the forest grades into drier coastal areas. Where the forest grades into wetter forests at higher elevations the canopy can be dominated by a transitional forest dominated by olopua (*Nestegis sandwicensis*) and papala kepau (*Pisonia brunoniana*). This transitional species assemblage occurs within the same soil map components as the rest of the ecological site. For mapping, it found in the lowest elevations of F161BY502 Kona Weather Udic Forest on westward-facing slopes in Kona and parts of Kau and in the highest elevations of the Kona Weather Dry Forest on southeastward-facing slopes in Kau.

Community 1.1
Lama - `ohi`a lehua/alahe`e

Figure 7. Reference community phase. D Clausnitzer generic photo

Figure 8. Nestegis-dominated variant. 11/1/05 D Clausnitzer MU112

Figure 9. Kainaliu series, a mineral volcanic ash soil

The tree canopy of the central concept of this community phase can be dominated by lama, ohia, or a combination of both. Within any given soil map component, geologic age may vary enough to affect the composition of the native plant community while the soils will lie within their central concepts. Ohia dominates the forest canopy on younger lava flows and lama dominates on slightly older flows within the same age category of the geology map that was referenced to create the soil map. Many species that are rare today, such as mountain sandalwood (*Santalum paniculatum*), ohe makai (*Reynoldsia sandwicensis*), wiliwili (*Erythrina sandwicensis*), and halapepe (*Pleomele hawaiiensis*) were more common as recently as the early 20th century. Native palm trees or loulu (*Pritchardia affinis* and *Pritchardia schattaueri*) have almost completely disappeared. This ecological site contains a remnant population of mehamehame (*Flueggea neowawraea*) trees. This species formerly grow to heights of 100 feet (30 meters) and diameters of 6 feet (2 meters). The trees now are in the form of stump shoots due to a fungus carried by the introduced black twig borer (Xylosandrus compactus). Because there has been so much disturbance by agriculture, fire, and ungulate activity, a digest, with updated plant scientific names, of the historical account by Joseph Rock (1913) follows to better describe the native plant community: On South Kona lava fields, dry forest trees were found down to the seashore, but tended to be small in stature in the very hot, dry areas nearest the ocean. The most common species near the shore were ohe makai (*Reynoldsia sandwicensis*), ohia lehua (*Metrosideros polymorpha*), and alahee (*Psydrax odorata*). Away from the shore and then throughout the rest of the dry forest the most common tree was halapepe (*Pleomele hawaiiensis*). The dry forest understory was sparse, containing nehe (Lipochaeta species), huehue (*Cocculus orbiculatus*), and anunu (*Sicyos anunu*). Native grasses included pili (*Heteropogon contortus*) and kakonakona (*Panicum torridum*). In the deeper ash soils on southeastern-facing slopes in Kau, aiea (*Nothocestrum breviflorum*) occurred; papala kepau (*Pisonia brunoniana*) and olopua (*Nestegis sandwicensis*) were very common, and hame (*Antidesma pulvinatum*) was present. On younger soils on aa and pahoehoe lavas on westward-facing slopes in Kau and Kona, ohia lehua and maua (Xylosma hawaiiense) were very common. Also present were hame and mamaki (*Pipturus albidus*). In some areas, kului (*Nototrichium sandwicense*) and halapepe formed the main plant growth along with hooawe (Pittosporum spp.), kopiko (Psychotria spp.), sandalwood (*Santalum paniculatum*), ohe makai, kauila (*Alphitonia ponderosa*), and manono (Hedyotis spp.). Below the highway to 1000 feet elevation, common plants were lama, wiliwili (*Erythrina sandwicensis*), ohe makai, alahee, pandanus (*Pandanus tectorius*), and the shrub maiapilo (*Capparis sandwichiana*) “to ten feet high.” Above 1000 feet were olopua, lama, kului, papala (*Charpentiera obovata*), papala kepau, two species of hame (*Antidesma platyphyllum* and pulvinatum), hooawe, halapepe, kopiko, maua, and an occasional kauila (*Colubrina oppositifolia*, a different “kauila” species from the one mentioned earlier). The other kauila (*Alphitonia ponderosa*) tended to be found on younger lava flows. Ohe makai and lama were stunted at lower elevations, but were up to 40-50 feet tall and 24 inch diameter at these higher elevations. The shrub ulei was abundant; it was erect, several inches thick, and 15-20 feet tall. There were only a few alaa (*Pouteria sandwicensis*), and sandalwood trees were small. Apparently uhiuhi trees (*Caesalpinia kavaiensis*) were rare, and Rock did not see the native hibiscus species present in F161BY500 Ustic Isothermic Forest, which is the similar dry forest in North Kona.

Forest overstory. The overstory is dominated by lama, ohia lehua, or a combination of these species. Tree species diversity varies from widely among locations. Higher, moister areas may be dominated by olopua (Nestegis sandwicensis). Pandanus or Tahitian screwpine (Pandanus tectorius) is found at lower elevations near the coast, but it is apparently much less abundant than in the past.

Forest understory. Alahee (Psydrax odorata), a small tree, is the most abundant species in the understory. Common shrubs are aalii (Dodonaea viscosa), ilima (Sida fallax), ulei (Osteomeles anthyllidifolia), and akia (Wikstroemia sandwicensis). In place, shrubby pilo species (Coprosma spp.) are common. Huehue (Cocculus orbiculatus) is the most common vine. Native forbs, grasses, and ferns are present but not abundant.

Table 5. Soil surface cover

Tree basal cover	3-4%
Shrub/vine/liana basal cover	0.5-1.0%
Grass/grasslike basal cover	0%
Forb basal cover	0%
Non-vascular plants	0-1%
Biological crusts	0%
Litter	60-70%
Surface fragments >0.25" and <=3"	0-40%
Surface fragments >3"	0-40%
Bedrock	0%

Water	0%
Bare ground	3-5%

Table 6. Woody ground cover

Downed wood, fine-small (<0.40" diameter; 1-hour fuels)	–
Downed wood, fine-medium (0.40-0.99" diameter; 10-hour fuels)	–
Downed wood, fine-large (1.00-2.99" diameter; 100-hour fuels)	1-1%
Downed wood, coarse-small (3.00-8.99" diameter; 1,000-hour fuels)	0-1%
Downed wood, coarse-large (>9.00" diameter; 10,000-hour fuels)	0-1%
Tree snags** (hard***)	–
Tree snags** (soft***)	–
Tree snag count** (hard***)	0-7 per hectare
Tree snag count** (hard***)	0-5 per hectare

*** Decomposition Classes: N - no or little integration with the soil surface; I - partial to nearly full integration with the soil surface.**

**** >10.16cm diameter at 1.3716m above ground and >1.8288m height--if less diameter OR height use applicable down wood type; for pinyon and juniper, use 0.3048m above ground.**

***** Hard - tree is dead with most or all of bark intact; Soft - most of bark has sloughed off.**

Table 7. Canopy structure (% cover)

Height Above Ground (M)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.15	0%	0-1%	0%	0%
>0.15 <= 0.3	0%	1-1%	0-1%	0-1%
>0.3 <= 0.6	0-1%	1-1%	0-1%	0-1%
>0.6 <= 1.4	2-3%	5-10%	–	–
>1.4 <= 4	15-25%	5-10%	–	–
>4 <= 12	45-55%	–	–	–
>12 <= 24	0-1%	–	–	–
>24 <= 37	–	–	–	–
>37	–	–	–	–

State 2
Invaded Understory State

This state consists of one community phase having an open canopy of common native trees with an understory of introduced grasses, ferns, vines, small trees, and shrubs. Foraging by feral or domestic ungulates removes native understory plants and prevents regeneration of overstory species, resulting in a mature and diminishing canopy of native trees. This may occur more gradually by weed invasion into intact native forest. The understory of this plant community contains fine fuels that are susceptible to wildfire.

Community 2.1
Lama - \`ohi\`a lehua/pukiawe/barbwire grass/scaly swordfern

Figure 10. Weed-invaded understory. 8/31/04 D Clausnitzer MU280

Native tree species dominate the overstory. The understory consists of a variable array of introduced plant species along with remnant native species.

Forest overstory. The overstory is dominated by lama, ohia lehua, or a combination of these species. Tree species diversity varies from widely among locations. Higher, moister areas may be dominated by olopua (Nestegis sandwicensis). Pandanus or Tahitian screwpine (Pandanus tectorius) is found at lower elevations near the coast, but it is apparently much less abundant than in the past.

Forest understory. Among native shrubs, aalii (Dodonaea viscosa) may still be common and pukiawe (Styphelia tameiameiae) may have increased. The introduced shrub lantana (Lantana camara) can be very abundant, producing stands that make foot transit difficult. The introduced vine huehue haole or corkystem passionflower (Passiflora suberosa) can become very abundant, covering the canopies of remnant native understory plants. Scaly swordfern (Nephrolepis hirsutula = N. multiflora) is a weedy introduced fern that may be abundant. Introduced grasses, particularly barbwire grass (Cymbopogon refractus) and, increasingly, fountaingrass (Pennisetum setaceum) are abundant where sufficient light penetrates the canopy. Christmasberry or Brazilian pepper tree (Schinus terebinthifolius), an introduced small tree that produces a dense, shady canopy, may be abundant.

Table 8. Soil surface cover

Tree basal cover	1-2%
Shrub/vine/liana basal cover	2-3%
Grass/grasslike basal cover	10-20%
Forb basal cover	3-5%
Non-vascular plants	0.5-1.0%
Biological crusts	0.5-1.0%
Litter	50-60%
Surface fragments >0.25" and <=3"	0-40%
Surface fragments >3"	0-40%
Bedrock	0%
Water	0%
Bare ground	0.5-1.0%

Table 9. Woody ground cover

Downed wood, fine-small (<0.40" diameter; 1-hour fuels)	–
Downed wood, fine-medium (0.40-0.99" diameter; 10-hour fuels)	–
Downed wood, fine-large (1.00-2.99" diameter; 100-hour fuels)	–

Downed wood, coarse-small (3.00-8.99" diameter; 1,000-hour fuels)	0-1%
Downed wood, coarse-large (>9.00" diameter; 10,000-hour fuels)	–
Tree snags** (hard***)	–
Tree snags** (soft***)	–
Tree snag count** (hard***)	
Tree snag count** (hard***)	

*** Decomposition Classes: N - no or little integration with the soil surface; I - partial to nearly full integration with the soil surface.**

**** >10.16cm diameter at 1.3716m above ground and >1.8288m height--if less diameter OR height use applicable down wood type; for pinyon and juniper, use 0.3048m above ground.**

***** Hard - tree is dead with most or all of bark intact; Soft - most of bark has sloughed off.**

Table 10. Canopy structure (% cover)

Height Above Ground (M)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.15	0%	1-1%	1-3%	0%
>0.15 <= 0.3	0%	1-1%	3-5%	1-2%
>0.3 <= 0.6	0%	1-1%	50-60%	5-10%
>0.6 <= 1.4	1-1%	5-10%	1-1%	–
>1.4 <= 4	5-10%	15-25%	–	–
>4 <= 12	10-50%	–	–	–
>12 <= 24	0-10%	–	–	–
>24 <= 37	–	–	–	–
>37	–	–	–	–

State 3
Naturalized Grassland State

This state consists of two community phases. It is naturalized grassland with introduced grasses, forbs, and trees. Scattered, large trees are often present. Some grasslands are on moderately deep and deep ash soils on former sugarcane plantations. Others were cleared from the original forest, and in many cases the underlying lava rock was ripped and crushed by heavy machinery to produce Ustarents (seasonally dry, sandy, organic soils). Ripping and crushing produces some fine mineral particles and reduces gap sizes between the rocks. However, about 50% of the soil organic matter may be lost in the process due to exposure to air and higher temperatures. This grassland evolved in recent history, and most of its constituent naturalized plants evolved in ecosystems in which herbivory and wildfire were important factors. Because this site can border along the ocean or contains gulches that reach the ocean, grass should be managed to control the movement of sediment from water erosion to meet current and future objectives of coastal zone management. Good vegetative condition is maintained with prescribed grazing and suppression of wildfire.

Community 3.1
White leadtree (koa haole)/guineagrass/glycine

Figure 11. Guineagrass with koa haole. D Clausnitzer generic photo

Figure 12. Guineagrass. D Clausnitzer generic photo

In grasslands dominated by guineagrass (*Urochloa maxima*), koa haole or white leadtree (*Leucaena leucocephala*), and glycine (*Neonotonia wightii*) and under good management, total annual, average, air-dry herbage production can range from 8,000 to 16,000 pounds per acre, and can average about 12,000 pounds per acre during an average or normal rainfall year. On very shallow soils or in dry extremes of this ecological site, herbage production may be only about 80% of those amounts. The major plant growth period is from mid-spring to early summer. Kikuyugrass (*Pennisetum clandestinum*) is suitable as an alternative for guineagrass in higher rainfall areas of this ecological site. These areas include higher elevations as well as sites near South Point that have Keaa cobbly medial loam (soil map units 290 and 291), Keaa-Kiolakaa complex (map unit 292), and Kiolakaa medial loam (map unit 305) that catch the edges of storms coming from the northeast. With continuous heavy grazing, particularly by cattle, preferred forage grasses decrease, as will preferred small trees, vines, and shrubs. Less preferred grass, forb, and shrub species increase under such circumstances. With severe deterioration, shrubby species can increase to eventually dominate.

Forest overstory. Opiuma (Pithecellobium dulce) and kiawe (Prosopis pallida) and large, spiny trees that are common in some of these grasslands.

Forest understory. Preferred forage species are guineagrass and Napier elephantgrass (Pennisetum purpureum), the vine glycine (Neonotonia wightii), and koa haole, a small tree.

Community 3.2
Barbwire grass - guineagrass

Figure 14. Guineagrass invaded by Andropogon virginicus. D Clausnitzer generic photo

This community phase is an open grassland dominated by introduced species having limited value to livestock and high susceptibility to fire. Key forage species such as guineagrass, koa haole, and glycine have been reduced to remnant amounts or eliminated. Less desirable species have increased in abundance and dominate the community. This community phase provides significantly less forage amounts than community phase 3.1. Introduced trees and shrubs gradually increase in the absence of fire.

Forest overstory. Opiuma (Pithecellobium dulce) and kiawe (Prosopis pallida) and large, spiny trees that are common in some of these grasslands.

Forest understory. Guineagrass is present in minor amounts. Primary increaser grass species that come to dominate this community under heavy grazing include pitted beardgrass (Bothriochloa pertusa), Natal redtop (Melinis repens), barbwiregrass (Cymbopogon refractus), feather fingergrass (Chloris virgata), Rhodesgrass (Chloris gayana), and wiregrass or Indian goosegrass (Eleusine indica), rattail (Sporobolus africanus), crabgrass (Digitaria pruriens), large crabgrass (Digitaria sanguinalis), Bermudagrass (Cynodon dactylon), Colombian bluestem (Schizachyrium condensatum), and broomsedge beardgrass (Andropogon virginicus). Unpalatable, increaser forbs include sensitive partridge pea (Chamaecrista nictitans), sensitive plant or shameplant (Mimosa pudica), rattlepod (Crotalaria mucronata), red pualele or lilac tasselflower (Emilia sonchifolia), common sow thistle (Sonchus oleraceus), lion’s ear mint (Leonotis nepetifolia), and spiny amaranth (Amaranthus spinosus). Shrubby species include lantana (Lantana camara), apple of Sodom (Solanum linnaeaum), false mallow (Malvastrum coromandelianum), cocklebur (Xanthium saccharatum), Sacramento bur (Triumfetta semitriloba), balloon plant (Asclepias physocarpa), christmasberry (Schinus terebinthifolius), hairy mallow (Abutilon grandifolia), and castor bean (Ricinus communis).

Table 11. Soil surface cover

Tree basal cover	0%
Shrub/vine/liana basal cover	0%
Grass/grasslike basal cover	30-35%
Forb basal cover	0%
Non-vascular plants	0.5-1.0%
Biological crusts	0%
Litter	40-50%
Surface fragments >0.25" and <=3"	0-40%
Surface fragments >3"	0-40%
Bedrock	0%
Water	0%
Bare ground	1-2%

Table 12. Canopy structure (% cover)

Height Above Ground (M)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.15	0%	0%	0-1%	0-1%
>0.15 <= 0.3	0%	0-1%	1-2%	1-1%
>0.3 <= 0.6	1-1%	1-1%	65-75%	1-1%
>0.6 <= 1.4	1-2%	1-1%	10-20%	–
>1.4 <= 4	1-2%	0-1%	–	–
>4 <= 12	0%	–	–	–
>12 <= 24	–	–	–	–
>24 <= 37	–	–	–	–
>37	–	–	–	–

Pathway 3.1A
Community 3.1 to 3.2

White leadtree (koa haole)/guineagrass/glycine

Barbwire grass - guineagrass

Community phase 3.1 converts to phase 3.2 by wildfire that reduces competitiveness of guineagrass and allows invasion of weeds, particularly undesirable grasses. Continuous grazing without adequate rest for preferred forages will have the same result. This conversion by either factor can be avoided if timely application of deferred and/or prescribed grazing is carried out to control guineagrass stature and to allow recovery of desirable species before weeds become dominant.

Pathway 3.2A
Community 3.2 to 3.1

Barbwire grass - guineagrass

White leadtree (koa haole)/guineagrass/glycine

Community phase 3.2 can be converted to phase 3.1 by removing undesirable species and favoring and/or reestablishing desirable pasture species. If adequate stands of guineagrass remain, prescribed grazing may eventually effect the conversion. Pitted beardgrass and Natal red top have some value as forage. However, barbwire grass, Colombian bluestem, and broomsedge beardgrass are very unpalatable to livestock and therefore difficult to control by grazing. Competitiveness of Colombian bluestem and broomsedge beardgrass may be reduced in pastures with acidic soils by liming the soil to increase pH. If pasture condition is very poor, weed control followed by reestablishment of guineagrass will be necessary.

State 4
Shrub-Invaded Grassland State

This state consists of one community phase. It may have developed from abandoned grazing land, land cleared by wildfire, or even long-abandoned Polynesian farmland. Shrubs are dominant in canopy cover and stature. Typically, an array of introduced grass species is present. There is a moderate but increasing cover of small trees, some which potentially can grow to large stature. This tree cover creates the potential for a transition to State 5 Exotic

Tree Invaded.

Community 4.1
Brazilian peppertree (christmasberry)/`a`ali`i - lantana/scaly swordfern

Figure 15. Site dominated by lantana. 6/04/04 D Clausnitzer MU100

The shrub community can be a mix of native and introduced species. The most common introduced trees present are christmasberry (*Schinus terebinthifolius*), koa haole (*Leucaena leucocephala*), and opiuma (*Pithecellobium dulce*). Remnant monkeypod (*Samanea saman*) trees may be present. When managed pastures have been abandoned and wildfires have not yet occurred, the plant community consists of very tall guineagrass and a dense stand of koa haole trees. In some cases, native shrubs are abundant. There may be a sparse, remnant population of small native trees; where these occur, it is possible that the site is long-abandoned farmland.

Forest overstory. The overstory most typically may contain christmasberry (Schinus terebinthifolius) and/or opiuma (Pithecellobium dulce). Lama (Diospyros sandwicensis) and/or ohia lehua (Metrosideros polymorpha) are the native trees most likely to be present.

Forest understory. Small trees that may be present are the introduced species christmasberry, opiuma, koa haole (Leucaena leucocephala), klu (Vachellia farnesiana), and common guava (Psidium guajava); native alahee (Psydrax odorata) is often present. Lantana (Lantana camara) is the most common shrub; native aalii (Dodonaea viscosa) is often abundant. Introduced scaly swordfern (Nephrolepis hirsutula) is usually abundant. The most common grasses are broomsedge bluestem (Andropogon virginicus) and molassesgrass (Melinis minutiflora), although guineagrass is dominant in some sites. Fountaingrass (Pennisetum setaceum) has been increasing its range in this ecological site.

Table 13. Soil surface cover

Tree basal cover	0-2%
Shrub/vine/liana basal cover	1-2%
Grass/grasslike basal cover	5-10%
Forb basal cover	0%
Non-vascular plants	0.0-0.5%
Biological crusts	0%
Litter	50-60%
Surface fragments >0.25" and <=3"	0-40%
Surface fragments >3"	0-40%
Bedrock	0%
Water	0%
Bare ground	5-10%

Table 14. Woody ground cover

Downed wood, fine-small (<0.40" diameter; 1-hour fuels)	–
Downed wood, fine-medium (0.40-0.99" diameter; 10-hour fuels)	–
Downed wood, fine-large (1.00-2.99" diameter; 100-hour fuels)	–
Downed wood, coarse-small (3.00-8.99" diameter; 1,000-hour fuels)	0%
Downed wood, coarse-large (>9.00" diameter; 10,000-hour fuels)	–
Tree snags** (hard***)	–
Tree snags** (soft***)	–
Tree snag count** (hard***)	
Tree snag count** (hard***)	

*** Decomposition Classes: N - no or little integration with the soil surface; I - partial to nearly full integration with the soil surface.**

**** >10.16cm diameter at 1.3716m above ground and >1.8288m height--if less diameter OR height use applicable down wood type; for pinyon and juniper, use 0.3048m above ground.**

***** Hard - tree is dead with most or all of bark intact; Soft - most of bark has sloughed off.**

Table 15. Canopy structure (% cover)

Height Above Ground (M)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.15	0%	1-2%	1-2%	0-1%
>0.15 <= 0.3	0%	1-2%	3-5%	1-1%
>0.3 <= 0.6	1-2%	5-10%	20-40%	1-2%
>0.6 <= 1.4	1-5%	20-25%	1-5%	–
>1.4 <= 4	10-40%	10-15%	–	–
>4 <= 12	0-1%	–	–	–
>12 <= 24	–	–	–	–
>24 <= 37	–	–	–	–
>37	–	–	–	–

State 5
Exotic Tree-Invaded State

This state is comprised of one community phase dominated by introduced trees. Density and composition of understory shrubs, forbs, and grasses varies greatly with overstory closure and height, which affects the susceptibility of this plant community to fire. The density, vigor, and biomass of introduced vegetation can be very high, making restoration to other states expensive and difficult.

Community 5.1
Brazilian peppertree (christmasberry)/lantana

Figure 16. Site dominated by exotic trees. D Clausnitzer generic photo

In many cases, the overstory consists of very dense christmasberry that is 15 to 25 feet (4.5 to 3.25 meters) tall with very little understory. Introduced tree species such as silk oak (*Grevillea robusta*), autograph tree (*Clusia rosea*), kukui (Aleurites moluccana), and octopus tree (*Schefflera actinophylla*) that have greater height potentials than christmasberry are often able to grow up through the christmasberry canopy and eventually dominate the site. Remnant, mature ohia lehua (*Metrosideros polymorpha*) trees may be present but are not able to regenerate. Native alahee (*Psydrax odorata*) trees sometimes are able to reproduce and maintain a sparse population in the understory. Although kukui is the State Tree of Hawaii, it was introduced to Hawaii by Polynesians; it is not indigenous and is considered to be invasive from the standpoint of conservation planning.

Forest overstory. The overstory composition can be highly variable from site to site, but christmasberry is typically the most abundant species.

Forest understory. Christmasberry often dominates the understory (<13 feet or 4 meters tall) and can be so dense as to exclude most other species. Native alahee sometimes persists in shady understory. Where more light is available, the small, introduced trees common guava (Psidium guajava) and koa haole (Leucaena leucocephala) are common. Lantana (Lantana camara) is by far the most common shrub to be found.

Table 16. Soil surface cover

Tree basal cover	4-5%
Shrub/vine/liana basal cover	0.5-1.0%
Grass/grasslike basal cover	0-1%
Forb basal cover	0%
Non-vascular plants	0-1%
Biological crusts	0%
Litter	55-65%
Surface fragments >0.25" and <=3"	0-40%
Surface fragments >3"	0-40%
Bedrock	0%
Water	0%
Bare ground	3-5%

Table 17. Woody ground cover

Downed wood, fine-small (<0.40" diameter; 1-hour fuels)	–
Downed wood, fine-medium (0.40-0.99" diameter; 10-hour fuels)	–
Downed wood, fine-large (1.00-2.99" diameter; 100-hour fuels)	–

Downed wood, coarse-small (3.00-8.99" diameter; 1,000-hour fuels)	0-1%
Downed wood, coarse-large (>9.00" diameter; 10,000-hour fuels)	0-1%
Tree snags** (hard***)	–
Tree snags** (soft***)	–
Tree snag count** (hard***)	2-7 per hectare
Tree snag count** (hard***)	2-7 per hectare

*** Decomposition Classes: N - no or little integration with the soil surface; I - partial to nearly full integration with the soil surface.**

**** >10.16cm diameter at 1.3716m above ground and >1.8288m height--if less diameter OR height use applicable down wood type; for pinyon and juniper, use 0.3048m above ground.**

***** Hard - tree is dead with most or all of bark intact; Soft - most of bark has sloughed off.**

Table 18. Canopy structure (% cover)

Height Above Ground (M)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.15	0%	0-1%	0%	0-1%
>0.15 <= 0.3	0%	0-1%	0-1%	0-1%
>0.3 <= 0.6	0%	1-1%	3-5%	0-1%
>0.6 <= 1.4	1-2%	10-15%	0-1%	–
>1.4 <= 4	25-35%	10-15%	–	–
>4 <= 12	45-55%	0-2%	–	–
>12 <= 24	0%	–	–	–
>24 <= 37	–	–	–	–
>37	–	–	–	–

Transition T1A
State 1 to 2

State 1 Reference transitions to State 2 Invaded Understory through grazing, browsing, rooting, and trampling by domestic or feral ungulates (cows, sheep, goats, and pigs). These activities destroy small native plant species and seedlings and saplings of large species. Regeneration of the native forest is prevented, leading to tree populations consisting almost entirely of mature plants. Lack of competition from native plants, introduction of weed seeds, and disturbance of the soil lead to an understory dominated by introduced plant species. Weeds can invade intact native forest even in the absence of ungulates and gradually bring about the transition. In particular, invasive vines, shrubs, and small trees will grow under intact native canopies and begin to degrade the forest. Eventually introduced grasses fine fuels that can carry catastrophic wildfires that destroy the native tree canopy.

Transition T1B
State 1 to 3

State 1 Reference transitions to State 3 Naturalized Grassland by clearing the forest with heavy machinery and planting desirable forage species. Where organic soils are very shallow or shallow over lava substrates, underlying lava rock may be ripped and crushed by heavy machinery to produce Ustarents (seasonally dry, sandy, organic) soils. Ripping and crushing produces some fine mineral particles and small, abundant gaps between rock fragments, producing a suitable rooting medium for many plants. About 50% of the soil organic matter may be lost in the process due to exposure to air and higher temperatures.

Restoration pathway R2A
State 2 to 1

State 2 may be restored to State 1 Reference, or to a facsimile of the Reference State, by removal of the introduced understory through application of herbicides and/or hand weeding. Reintroduction of native understory species is required. The site must be fenced securely to exclude ungulates.

Transition T2A
State 2 to 3

State 2 transitions to State 3 Naturalized Grassland by land clearing with heavy machinery followed up by weed control. Land clearing would probably promote germination of the weed seed bank in the soil, requiring herbicidal control. After clearing and weed control, the site would be planted to forage species.

Transition T2B
State 2 to 5

State 2 transitions to State 5 Exotic Tree Invaded by growth of introduced tree species through and above the native canopy. Lack of reproduction leads to gradual loss of most native tree species.

Restoration pathway R3A
State 3 to 1

It may be possible to restore State 3 to a plant community resembling State 1 Reference. Weed control would be applied to forage species and the many opportunistic plant species that would invade the site. Weed control would be a perpetual process to maintain the site. Fire and domestic and feral ungulates would have to be excluded. Extensive planting of native species would follow. On sites where the soils have been converted to Ustarents by ripping and crushing by heavy machinery, restoration of at least some native species is possible (Jill Wagner, personal communication). Ustarents appear to be a very favorable seedbed for weeds.

Transition T3A
State 3 to 4

State 3 transitions to State 4 Shrub Invaded Grassland after abandonment and, if wildfires do not occur, gradual invasion of weedy shrubs and small trees. If the site contained abundant koa haole before abandonment, these small trees will overtop the guineagrass and greatly increase their cover.

Restoration pathway R4A
State 4 to 3

This state can be restored to State 3 Naturalized Grassland by brush management with follow-up control of resprouting shrubs and emerging weedy forbs. Forage species may then be replanted and maintained by prescribed grazing. For large, densely weedy sites or if fast results are not required, it is possible to eliminate invasive small trees, shrubs, and undergrowth by planting glycine (*Neonotonia wightii*) to overtop and shade out weeds; this is done in conjunction with foraging by sheep and goats to consume smaller weeds. Eventually, the dead trees and shrubs collapse under the weight of the glycine; the glycine is then eaten by the livestock. This process takes about eight years (Gordon Cran, Kapapala Ranch, personal communication, 2006).

Transition T4A
State 4 to 5

This state transitions to State 5 Exotic Tree Invaded with lack of wildfire. Fast-growing introduced tree species invade Shrub Invaded Grassland and quickly overtop shrubs.

Restoration pathway R5A
State 5 to 1

It may be possible to restore this state to a community resembling State 1 Reference. Total clearing of the site would be necessary. Alternatively, it may be worthwhile to kill taller weed species in place by herbicide applications in order to provide some shelter from the sun. If clearing is done by heavy machinery, soil disturbance would occur. This would produce unknown conditions with regard to native plant establishment and probably induce germination of the weed seed bank and increase the potential for soil erosion and loss of organic matter by oxidation. Weed control and brush management would be long-term. Fire and ungulates would have to be excluded. Heavy machinery use can be avoided in the case of christmasberry trees by killing the trees with glycine vines coupled with sheep and goat browsing, a process that takes about eight years (Gordon Cran, Kapapala Ranch, personal communication, 2006). Glycine would have to be eliminated later by grazing and herbicides before forest restoration could be successful.

Restoration pathway R5B
State 5 to 3

This state may be restored to State 3 Naturalized Grassland. Total clearing of the site would be necessary. If clearing is done by heavy machinery, soil disturbance would occur. This would probably induce germination of the weed seed bank and increase the potential for soil erosion and loss of organic matter by oxidation. Weed control and brush management must then be applied multiple times to control new weed germination and resprouting. After clearing and weed control, the site would be planted to forage species. Ungulates would have to be excluded until forages are well established; prescribed grazing must then be applied. Heavy machinery use can be avoided in the case of christmasberry trees by killing the trees with glycine vines coupled with sheep and goat browsing, a process that takes about eight years (Gordon Cran, Kapapala Ranch, personal communication, 2006). Glycine would have to be eliminated later by grazing and herbicides before forest restoration could be successful.

Additional community tables

Table 19. Community 1.1 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)	Diameter (Cm)	Basal Area (Square M/Hectare)
Tree							
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	12.2–27.4	0–60	10.2–101.6	–
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	4–12.2	0–60	–	–
lama	DISA10	*Diospyros sandwicensis*	Native	4–12.2	0–55	5.1–30.5	–
Hawai'i olive	NESA2	*Nestegis sandwicensis*	Native	4–18.3	0–50	–	–
Australasian catchbirdtree	PIBR3	*Pisonia brunoniana*	Native	4–12.2	0–5	–	–
lama	DISA10	*Diospyros sandwicensis*	Native	12.2–16.8	0–5	20.3–35.6	–
wili wili	ERSA11	*Erythrina sandwicensis*	Native	4–12.2	0–1	–	–
'ohe makai	RESA	*Reynoldsia sandwicensis*	Native	4–15.2	0–1	–	–
cheesewood	PITTO	*Pittosporum*	Native	4–12.2	0–1	–	–
kolea lau nui	MYLE2	*Myrsine lessertiana*	Native	4–12.2	0–1	–	–
wild coffee	PSYCH	*Psychotria*	Native	4–9.1	0–1	–	–
Hawai'i brushholly	XYHA	*Xylosma hawaiiensis*	Native	4–12.2	0–0.5	–	–
tetraplasandra	TETRA11	*Tetraplasandra*	Native	4–12.2	0–0.5	–	–
Hawai'i kauilatree	ALPO3	*Alphitonia ponderosa*	Native	4–12.2	–	–	–
mountain sandalwood	SAPA7	*Santalum paniculatum*	Native	4–9.1	–	–	–
lands of papa pritchardia	PRSC	*Pritchardia schattaueri*	Native	4–36.6	–	–	–
aulu	PISA5	*Pisonia sandwicensis*	Native	4–12.2	–	–	–
Hawai'i hala pepe	PLHA4	*Pleomele hawaiiensis*	Native	4–4.6	–	–	–
Hawai'i pritchardia	PRAF	*Pritchardia affinis*	Native	9.1–15.2	–	–	–
mamani	SOCH	*Sophora chrysophylla*	Native	4–4.6	–	–	–
Tahitian screwpine	PATE2	*Pandanus tectorius*	Native	4–6.1	–	–	–
mehamehame	FLNE	*Flueggea neowawraea*	Native	0.6–30.5	–	2.5–182.9	–
Hawai'i roughbush	STPE3	*Streblus pendulinus*	Native	4–7.6	–	–	–

Table 20. Community 1.1 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
tanglehead	HECO10	*Heteropogon contortus*	Native	0.3–0.6	0–1
torrid panicgrass	PATO	*Panicum torridum*	Native	0.3–0.6	0–0.1
Oahu sedge	CAWA	*Carex wahuensis*	Native	0.3–0.6	–
Forb/Herb					

Forb/Herb					
nehe	LIPOC2	*Lipochaeta*	Native	0.3–0.6	0–0.5
peperomia	PEPER	*Peperomia*	Native	0.2–0.3	0–0.2
Big Island ma'oloa	NEOV	*Neraudia ovata*	Native	0.3–0.6	–
Fern/fern ally					
Boston swordfern	NEEX	*Nephrolepis exaltata*	Native	0.3–0.6	0–0.5
staghorn clubmoss	LYCE2	*Lycopodiella cernua*	Native	0.1–0.2	0–0.5
graceful kihifern	ADPI	*Adenophorus pinnatifidus*	Native	0.1–0.2	0–0.5
royal tonguefern	ELCR2	*Elaphoglossum crassifolium*	Native	0.1–0.2	0–0.5
whisk fern	PSNU	*Psilotum nudum*	Native	0.2–0.3	0–0.1
weeping fern	LETH6	*Lepisorus thunbergianus*	Native	0.2–0.3	–
Shrub/Subshrub					
Florida hopbush	DOVI	*Dodonaea viscosa*	Native	0.6–1.8	1–10
yellow ‘ilima	SIFA	*Sida fallax*	Native	0.6–0.9	0–5
Hawai'i hawthorn	OSAN	*Osteomeles anthyllidifolia*	Native	0.6–1.8	1–5
variableleaf false ohelo	WISA	*Wikstroemia sandwicensis*	Native	0.6–2.4	0–3
Hawai'i rockwort	NOSA	*Nototrichium sandwicense*	Native	0.6–2.4	0–0.5
Gaudichaud's senna	SEGA2	*Senna gaudichaudii*	Native	0.6–2.4	0–0.5
'ekoko	CHCE	*Chamaesyce celastroides*	Native	0.6–3	0–0.5
variable sandmat	CHMU3	*Chamaesyce multiformis*	Native	0.6–1.5	0–0.2
wahine noho kula	ISPY	*Isodendrion pyrifolium*	Native	0.6–0.9	–
uhaloa	WAIN	*Waltheria indica*	Native	0.3–0.6	–
Tree					
lama	DISA10	*Diospyros sandwicensis*	Native	0.6–4	0–10
Pringle's bird's beak	COPR	*Cordylanthus pringlei*	Native	0.6–3	0–5
naio	MYSA	*Myoporum sandwicense*	Native	0.6–4	0–1
variable starviolet	HETE21	*Hedyotis terminalis*	Native	0.6–4	0–0.5
hame	ANPU2	*Antidesma pulvinatum*	Native	0.6–4	0–0.5
mountain sandalwood	SAPA7	*Santalum paniculatum*	Native	0.6–4	0–0.5
mamani	SOCH	*Sophora chrysophylla*	Native	0.6–4	0–0.5
Hawai'i brushholly	XYHA	*Xylosma hawaiiensis*	Native	0.6–4	0–0.2
Tahitian screwpine	PATE2	*Pandanus tectorius*	Native	0.6–4	0–0.1
mokihana kukae moa	MEHA4	*Melicope hawaiensis*	Native	0.6–4	–
Hawai'i treecotton	KODR	*Kokia drynarioides*	Native	0.6–4	–
papala	CHARP	*Charpentiera*	Native	0.6–4	–
wili wili	ERSA11	*Erythrina sandwicensis*	Native	0.6–4	–
'ohe makai	RESA	*Reynoldsia sandwicensis*	Native	0.6–4	–
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	0.6–4	–
'ahakea	BOTI	*Bobea timonioides*	Native	0.6–4	–
Hawai'i kauilatree	ALPO3	*Alphitonia ponderosa*	Native	0.6–4	–
kauila	COOP	*Colubrina oppositifolia*	Native	0.6–4	–
Hawai'i hala pepe	PLHA4	*Pleomele hawaiiensis*	Native	0.6–4	–
Tree Fern					
hapu'u	CIGL	*Cibotium glaucum*	Native	1.8–2.4	–

Vine/Liana					
devil's gut	CAFI4	*Cassytha filiformis*	Native	0.2–15.2	0.5–2
queen coralbead	COOR11	*Cocculus orbiculatus*	Native	0.2–3	0.2–1
Maile	ALST11	*Alyxia stellata*	Native	0.3–0.9	0–0.5
puakauhi	CAHA12	*Canavalia hawaiiensis*	Native	0.3–1.5	0–0.5
kilioe	EMPA	*Embelia pacifica*	Native	0.3–0.6	–

Table 21. Community 2.1 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)	Diameter (Cm)	Basal Area (Square M/Hectare)
Tree							
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	4–12.2	0–50	–	–
Hawai'i olive	NESA2	*Nestegis sandwicensis*	Native	4–15.2	0–50	–	–
lama	DISA10	*Diospyros sandwicensis*	Native	4–12.2	0–50	–	–
Brazilian peppertree	SCTE	*Schinus terebinthifolius*	Introduced	4–6.1	1–20	–	–
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	12.2–21.3	0–5	–	–
mamani	SOCH	*Sophora chrysophylla*	Native	4–6.1	0–1	–	–

Table 22. Community 2.1 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
barbwire grass	CYRE	*Cymbopogon refractus*	Introduced	0.3–0.6	20–60
Colombian bluestem	SCCO10	*Schizachyrium condensatum*	Introduced	0.6–0.9	1–5
guineagrass	URMA3	*Urochloa maxima*	Introduced	0.9–1.5	0–2
basketgrass	OPHI	*Oplismenus hirtellus*	Introduced	0.3–0.6	1–2
crimson fountaingrass	PESE3	*Pennisetum setaceum*	Introduced	0.3–0.6	0–1
Forb/Herb					
spreading snakeroot	AGRI2	*Ageratina riparia*	Introduced	0.3–0.6	0–1
Fern/fern ally					
scaly swordfern	NEHI	*Nephrolepis hirsutula*	Introduced	0.3–0.6	2–10
Shrub/Subshrub					
lantana	LACA2	*Lantana camara*	Introduced	0.6–1.8	2–30
pukiawe	STTA	*Styphelia tameiameiae*	Native	0.6–1.8	1–20
Florida hopbush	DOVI	*Dodonaea viscosa*	Native	0.6–1.8	1–10
Hawai'i hawthorn	OSAN	*Osteomeles anthyllidifolia*	Native	0.6–1.5	0–2
variableleaf false ohelo	WISA	*Wikstroemia sandwicensis*	Native	0.6–2.4	0–0.5
Tree					
Brazilian peppertree	SCTE	*Schinus terebinthifolius*	Introduced	0.6–4	1–10
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	0.6–4	0–5
mamani	SOCH	*Sophora chrysophylla*	Native	1.5–4	0–1
Vine/Liana					
corkystem passionflower	PASU3	*Passiflora suberosa*	Introduced	0.3–1.5	1–20
shoofly	CADE15	*Caesalpinia decapetala*	Introduced	0.6–1.2	0–3
queen coralbead	COOR11	*Cocculus orbiculatus*	Native	0.3–1.2	0–1

Table 23. Community 3.1 plant community composition

Group	Common Name	Symbol	Scientific Name	Annual Production (Kg/Hectare)	Foliar Cover (%)
Grass/Grasslike					
1	**Naturalized Warm Season Tallgrasses**			10760–11433	
	guineagrass	URMA3	*Urochloa maxima*	10760–11433	–
	elephant grass	PEPU2	*Pennisetum purpureum*	0–135	–
2	**Naturalized Warm Season Midgrasses**			0–404	
	broomsedge bluestem	ANVI2	*Andropogon virginicus*	0–135	–
	pitted beardgrass	BOPE2	*Bothriochloa pertusa*	0–135	–
	Rhodes grass	CHGA2	*Chloris gayana*	0–135	–
	feather fingergrass	CHVI4	*Chloris virgata*	0–135	–
	barbwire grass	CYRE	*Cymbopogon refractus*	0–135	–
	hairy crabgrass	DISA	*Digitaria sanguinalis*	0–135	–
	Indian goosegrass	ELIN3	*Eleusine indica*	0–135	–
	rose Natal grass	MERE9	*Melinis repens*	0–135	–
	Colombian bluestem	SCCO10	*Schizachyrium condensatum*	0–135	–
3	**Naturalized Warm Season Shortgrasses**			0–135	

3	**Naturalized Warm Season Shortgrasses**			0–135	
	Bermudagrass	CYDA	*Cynodon dactylon*	0–135	–
Forb					
4	**Naturalized Forbs**			135–673	
	perennial soybean	NEWI2	*Neonotonia wightii*	135–404	–
	sensitive partridge pea	CHNI2	*Chamaecrista nictitans*	135–269	–
	smooth rattlebox	CRPAO	*Crotalaria pallida var. obovata*	0–135	–
	lilac tasselflower	EMSO	*Emilia sonchifolia*	0–135	–
	Christmas candlestick	LENE	*Leonotis nepetifolia*	0–135	–
	shameplant	MIPU8	*Mimosa pudica*	0–135	–
	common sowthistle	SOOL	*Sonchus oleraceus*	0–135	–
	spiny amaranth	AMSP	*Amaranthus spinosus*	0–135	–
Shrub/Vine					
5	**Naturalized Shrubs and Trees**			2690–5380	
	white leadtree	LELE10	*Leucaena leucocephala*	2690–4708	–
	kiawe	PRPA4	*Prosopis pallida*	135–673	–
	anil de pasto	INSU	*Indigofera suffruticosa*	135–404	–
	lantana	LACA2	*Lantana camara*	0–135	–
	castorbean	RICO3	*Ricinus communis*	0–135	–
	Brazilian peppertree	SCTE	*Schinus terebinthifolius*	0–135	–
	Sacramento burbark	TRSE4	*Triumfetta semitriloba*	0–135	–
	sweet acacia	VAFA	*Vachellia farnesiana*	0–135	–
	Canada cocklebur	XASTC	*Xanthium strumarium var. canadense*	0–135	–
	threelobe false mallow	MACO6	*Malvastrum coromandelianum*	0–135	–
	monkeypod	PIDU	*Pithecellobium dulce*	0–135	–
	cure for all	PLCA10	*Pluchea carolinensis*	0–135	–
	hairy Indian mallow	ABGR3	*Abutilon grandifolium*	0–135	–
	balloonplant	ASPH2	*Asclepias physocarpa*	0–135	–

Table 24. Community 3.2 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)	Diameter (Cm)	Basal Area (Square M/Hectare)
Tree							
monkeypod	PIDU	*Pithecellobium dulce*	Introduced	4–15.2	0–20	–	–
kiawe	PRPA4	*Prosopis pallida*	Introduced	4–7.6	0–10	–	–
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	4–12.2	–	–	–
silkoak	GRRO	*Grevillea robusta*	Introduced	4–12.2	–	–	–

Table 25. Community 3.2 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
guineagrass	URMA3	*Urochloa maxima*	Introduced	0.9–1.2	5–60
barbwire grass	CYRE	*Cymbopogon refractus*	Introduced	0.3–0.6	10–60

barbwire grass	CYRE2	*Cymbopogon refractus*	Introduced	[illegible]	[illegible]
Colombian bluestem	SCCO10	*Schizachyrium condensatum*	Introduced	0.6–0.9	0–50
broomsedge bluestem	ANVI2	*Andropogon virginicus*	Introduced	0.6–0.9	1–40
Bermudagrass	CYDA	*Cynodon dactylon*	Introduced	0.1–0.2	1–5
pitted beardgrass	BOPE2	*Bothriochloa pertusa*	Introduced	0.3–0.6	0–3
feather fingergrass	CHVI4	*Chloris virgata*	Introduced	0.3–0.6	0–3
Indian goosegrass	ELIN3	*Eleusine indica*	Introduced	0.2–0.3	0–2
hairy crabgrass	DISA	*Digitaria sanguinalis*	Introduced	0.3–0.6	0–1
molassesgrass	MEMI2	*Melinis minutiflora*	Introduced	0.3–0.6	0–1
East Indian crabgrass	DISE6	*Digitaria setigera*	Introduced	0.3–0.6	0–1
annual rabbitsfoot grass	POMO5	*Polypogon monspeliensis*	Introduced	0.2–0.3	0–1
Forb/Herb					
ticktrefoil	DESMO	*Desmodium*	Introduced	0.3–0.6	0–1
sensitive partridge pea	CHNI2	*Chamaecrista nictitans*	Introduced	0.1–0.2	0–1
nodeweed	SYNO	*Synedrella nodiflora*	Introduced	0.1–0.2	0–1
smooth rattlebox	CRPAO	*Crotalaria pallida var. obovata*	Introduced	0.6–0.9	0–1
lilac tasselflower	EMSO	*Emilia sonchifolia*	Introduced	0.3–0.6	0–1
common sowthistle	SOOL	*Sonchus oleraceus*	Introduced	0.3–0.6	0–1
shameplant	MIPU8	*Mimosa pudica*	Introduced	0.1–0.2	0–1
Christmas candlestick	LENE	*Leonotis nepetifolia*	Introduced	0.3–0.6	0–1
spiny amaranth	AMSP	*Amaranthus spinosus*	Introduced	0.3–0.9	0–1
anil de pasto	INSU	*Indigofera suffruticosa*	Introduced	0.3–0.9	0–1
hairy Indian mallow	ABGR3	*Abutilon grandifolium*	Introduced	0.6–0.9	0–0.5
threelobe false mallow	MACO6	*Malvastrum coromandelianum*	Introduced	0.6–0.9	0–0.5
Sacramento burbark	TRSE4	*Triumfetta semitriloba*	Introduced	0.6–0.9	0–0.5
balloonplant	ASPH2	*Asclepias physocarpa*	Introduced	0.6–0.9	0–0.5
Canada cocklebur	XASTC	*Xanthium strumarium var. canadense*	Introduced	0.6–0.9	0–0.5
Fern/fern ally					
scaly swordfern	NEHI	*Nephrolepis hirsutula*	Introduced	0.3–0.6	0–1
Shrub/Subshrub					
lantana	LACA2	*Lantana camara*	Introduced	0.6–1.2	0–1
pukiawe	STTA	*Styphelia tameiameiae*	Native	0.6–1.5	0–1
cure for all	PLCA10	*Pluchea carolinensis*	Introduced	0.6–1.2	0–1
castorbean	RICO3	*Ricinus communis*	Introduced	0.9–1.8	0–0.5
uhaloa	WAIN	*Waltheria indica*	Native	0.2–0.3	–
Tree					
Brazilian peppertree	SCTE	*Schinus terebinthifolius*	Native	0.6–4	0–2
monkeypod	PIDU	*Pithecellobium dulce*	Introduced	0.6–1.5	0–1
white leadtree	LELE10	*Leucaena leucocephala*	Introduced	0.6–1.5	0–0.5
sweet acacia	VAFA	*Vachellia farnesiana*	Introduced	0.6–1.2	0–0.5
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	0.6–4	–
guava	PSGU	*Psidium guajava*	Introduced	0.6–0.9	–
mamani	SOCH	*Sophora chrysophylla*	Native	0.6–1.5	–
Vine/Liana					

queen coralbead	COOR11	*Cocculus orbiculatus*	Native	0.2–0.3	–

Table 26. Community 4.1 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)	Diameter (Cm)	Basal Area (Square M/Hectare)
Tree							
Brazilian peppertree	SCTE	*Schinus terebinthifolius*	Introduced	4–4.6	0–40	–	–
monkeypod	PIDU	*Pithecellobium dulce*	Introduced	4–15.2	0–20	–	–
lama	DISA10	*Diospyros sandwicensis*	Native	4–6.1	–	–	–
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	4–12.2	–	–	–

Table 27. Community 4.1 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
broomsedge bluestem	ANVI2	*Andropogon virginicus*	Introduced	0.6–0.9	10–20
molassesgrass	MEMI2	*Melinis minutiflora*	Introduced	0.3–0.6	5–10
guineagrass	URMA3	*Urochloa maxima*	Introduced	0.9–1.2	1–5
rose Natal grass	MERE9	*Melinis repens*	Introduced	0.3–0.6	3–5
crimson fountaingrass	PESE3	*Pennisetum setaceum*	Introduced	0.6–0.9	0–1
Forb/Herb					
sensitive partridge pea	CHNI2	*Chamaecrista nictitans*	Introduced	0.2–0.3	0–1
spreading snakeroot	AGRI2	*Ageratina riparia*	Introduced	0.3–0.6	0–1
shameplant	MIPU8	*Mimosa pudica*	Introduced	0.2–0.3	0–1
Fern/fern ally					
scaly swordfern	NEHI	*Nephrolepis hirsutula*	Introduced	0.3–0.6	5–20
musk fern	PHGR61	*Phymatosorus grossus*	Introduced	0.3–0.6	1–5
Shrub/Subshrub					
lantana	LACA2	*Lantana camara*	Introduced	0.6–1.8	5–25
Florida hopbush	DOVI	*Dodonaea viscosa*	Native	0.6–1.8	10–20
dogtail	BUAS	*Buddleja asiatica*	Introduced	0.9–2.4	1–5
comb bushmint	HYPE3	*Hyptis pectinata*	Introduced	0.6–2.4	1–5
yellow ‘ilima	SIFA	*Sida fallax*	Native	0.6–1.2	0–1
cure for all	PLCA10	*Pluchea carolinensis*	Introduced	0.6–1.5	0–1
anil de pasto	INSU	*Indigofera suffruticosa*	Introduced	0.3–0.9	0–0.5
sisal hemp	AGSI2	*Agave sisalana*	Introduced	1.8–2.4	–
uhaloa	WAIN	*Waltheria indica*	Native	0.3–0.6	–
Tree					
white leadtree	LELE10	*Leucaena leucocephala*	Introduced	0.6–4	5–75
Brazilian peppertree	SCTE	*Schinus terebinthifolius*	Introduced	0.6–4	10–40
sweet acacia	VAFA	*Vachellia farnesiana*	Introduced	0.6–4	0–5
guava	PSGU	*Psidium guajava*	Introduced	0.6–2.4	0–1
alahe'e	PSOD	*Psydrax odorata*	Native	0.6–2.4	0–0.5
lama	DISA10	*Diospyros sandwicensis*	Native	1.5–4	–
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Introduced	1.5–4	–
Vine/Liana					
corkystem passionflower	PASU3	*Passiflora suberosa*	Introduced	0.3–1.5	1–5
devil's gut	CAFI4	*Cassytha filiformis*	Native	0.3–9.1	1–5
queen coralbead	COOR11	*Cocculus orbiculatus*	Native	0.3–1.2	0–1

Table 28. Community 5.1 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)	Diameter (Cm)	Basal Area (Square M/Hectare)
Tree							
Brazilian peppertree	SCTE	*Schinus terebinthifolius*	Introduced	4–6.1	35–45	–	–
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	4–21.3	0–5	–	–
silkoak	GRRO	*Grevillea robusta*	Introduced	4–15.2	0–5	–	–
Scotch attorney	CLRO	*Clusia rosea*	Introduced	4–12.2	0–5	–	–
octopus tree	SCAC2	*Schefflera actinophylla*	Introduced	4–12.2	1–5	–	–

Table 29. Community 5.1 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
basketgrass	OPHI	*Oplismenus hirtellus*	Introduced	0.3–0.6	5–10
guineagrass	URMA3	*Urochloa maxima*	Introduced	0.6–1.2	0–2
molassesgrass	MEMI2	*Melinis minutiflora*	Introduced	0.3–0.6	0–1
rose Natal grass	MERE9	*Melinis repens*	Introduced	0.3–0.6	0–1
Forb/Herb					
sensitive partridge pea	CHNI2	*Chamaecrista nictitans*	Introduced	0.2–0.3	0–1
spreading snakeroot	AGRI2	*Ageratina riparia*	Introduced	0.3–0.6	0–1
shameplant	MIPU8	*Mimosa pudica*	Introduced	0.2–0.3	0–1
peperomia	PEPER	*Peperomia*	Native	0.2–0.3	–
Fern/fern ally					
scaly swordfern	NEHI	*Nephrolepis hirsutula*	Introduced	0.3–0.6	10–25
whisk fern	PSNU	*Psilotum nudum*	Native	0.2–0.3	–
Shrub/Subshrub					
lantana	LACA2	*Lantana camara*	Introduced	0.6–1.2	0–20
cure for all	PLCA10	*Pluchea carolinensis*	Introduced	0.6–1.2	0–1
dogtail	BUAS	*Buddleja asiatica*	Introduced	1.2–1.8	0–1
comb bushmint	HYPE3	*Hyptis pectinata*	Introduced	0.6–1.8	0–1
Florida hopbush	DOVI	*Dodonaea viscosa*	Native	0.9–1.5	–
uhaloa	WAIN	*Waltheria indica*	Native	0.3–0.6	–
Tree					
Brazilian peppertree	SCTE	*Schinus terebinthifolius*	Introduced	0.6–4	25–35
guava	PSGU	*Psidium guajava*	Introduced	0.6–4	0–2
white leadtree	LELE10	*Leucaena leucocephala*	Introduced	0.6–2.4	0–1
silkoak	GRRO	*Grevillea robusta*	Introduced	0.6–4	0–1
Scotch attorney	CLRO	*Clusia rosea*	Introduced	0.6–4	0–1
octopus tree	SCAC2	*Schefflera actinophylla*	Introduced	0.6–4	0–1
Vine/Liana					
corkystem passionflower	PASU3	*Passiflora suberosa*	Introduced	0.6–1.5	1–5
shoofly	CADE15	*Caesalpinia decapetala*	Introduced	0.9–1.5	0–1
devil's gut	CAFI4	*Cassytha filiformis*	Native	0.3–9.1	0–1
Hawai'i pearls	CAMA21	*Caesalpinia major*	Native	0.6–1.5	0–0.5
queen coralbead	COOR11	*Cocculus orbiculatus*	Native	0.3–0.6	–

Animal community

Native Wildlife
Community phases that provide open grassland or shrubland provide habitat for the native Hawaiian hawk or io (Buteo solitarius) and Hawaiian owl or pueo (Asio flammeus spp. sandwichensis).

A large number of native bird species have gone extinct both before and after European contact.

Introduced Wildlife
This ecological site provides habitat to a variety of introduced birds. Species such as wild turkey (Meleagris gallopavo), ring-necked pheasant (Phasianus colchicus), Erckel’s francolin (Pternistis erckelii), and black francolin

(Francolinus francolinus) are considered to be game birds.

Feral pigs and goats are common. They provide hunting opportunities but are very destructive to native vegetation. Public sport hunting typically does not have a major impact on their populations; exclusion by fences followed by intensive control measures are necessary to eliminate feral ungulates.

Introduced wildlife species are able to utilize all community phases within the ecological site.

Grazing Interpretations
The following table lists suggested initial stocking rates for cattle under the Forage Value Rating system for only community phase 3.1. These are conservative estimates that should be used only as guidelines in the initial stages of the conservation planning process. Sometimes the current plant composition does not entirely match any particular plant community described in this ecological site description. Because of this, a field visit is recommended to document plant composition and production. More precise carrying capacity estimates should eventually be calculated using the following stocking rate information along with animal preference data, particularly when grazers other than cattle are involved. Under more intensive grazing management, improved harvest efficiencies may result in an increased stocking rate.

Forage Value Rating (note 1)

Very High (note 2) 0.20-0.22 acre/AUM (note 3) 5.13-4.49 AUM/acre

High 0.22-0.26 acre/AUM 4.49-3.85 AUM/acre

Moderate 0.26-0.39 acre/AUM 3.85-2.56 AUM/acre

Low 0.39-+ acre/AUM 2.56-+ AUM/acre

(note 1) The Forage Value Rating System is not an ecological evaluation of community phase 3.1. It is a utilitarian rating of the existing forage value for that specific plant community.

(note 2) Conservationists must use considerable judgment, because some pastures in the Very High forage class could be producing less than normal volumes of forage, and adjustments would need to be made in the initial stocking rate.

(note 3) Stocking rates vary in accordance with such factors as kind and class of livestock or wildlife, season of use, and fluctuations in climate. Actual use records and on-site inventories for individual sites, together with a determination of the degree to which the sites have been grazed, offer the most reliable basis for developing initial stocking rates.

This community phase is suitable for grazing by all kinds and classes of livestock, at any season, particularly cattle. This site is suited for grazing by both cow-calf operations and stocker operations. Sheep can be grazed on this site as well. This site is poorly suited to continuous year-long use if desired forages are to be maintained. Herbaceous forage can be deficient in protein during the drier months.

Hydrological functions

Where this ecological site is covered with deep ash soils, infiltration, runoff, and soil erosion conditions are good on well-vegetated sites. However, temporary water flows in shallow gulches can cause excessive erosion. Soil erosion was high when these deep soil sites were cultivated for sugar cane, creating zones of deep accumulation on level areas downhill.

Much of the ecological site consists of soils formed in crevices between cobbles in aa lava flows; these soils accept water at high rates, leading to negligible to very low runoff rates on all slopes. Very shallow soils formed over pahoehoe exhibit negligible runoff in depressions on gentle slopes and high to very high runoff on steeper slopes.

Recreational uses

Extensive lava fields, hot climate, abundance of mosquitos, and dense weeds on much of this ecological site limit recreational uses. Hunting is the most common recreational use.

Wood products

There are currently no wood products harvested commercially from this ecological site.

Other products

None.

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.

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 and duration 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.

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.

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.

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

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

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

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

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

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

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

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

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

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

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

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

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.

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.

Type locality

Location 1: Hawaii County, HI	
Latitude	19° 7′ 5″
Longitude	155° 51′ 2″
General legal description	Island of Hawaii, South Kona District, USGS Quad: Pohue Bay. Manuka Forest Reserve. Drive 1.2 miles makai from Hwy. 11 on jeep trail to ocean. Walk 50 m to SE into forest.

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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	
Approved by	
Approval date	
Composition (Indicators 10 and 12) based on	Annual Production

Indicators

1. **Number and extent of rills:**

2. **Presence of water flow patterns:**

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

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

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

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

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

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

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

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

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

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

    Dominant:

    Sub-dominant:

    Other:

    Additional:

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:**