Ecological site VX160X01X502
Isomesic-Cool Isothermic 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): 160X–Subhumid and Humid Intermediate and High Mountain Slopes

This MLRA occurs in the State of Hawaii on the Big Island of Hawaii and to a small extent on Maui. Elevation ranges from 1000 to 9000 feet (300 to 2725 meters). Slopes are moderate to steep. Topography is sloping to hilly, and cinder cones are common. Lava flows are basaltic or andesitic aa or pahoehoe lava. Aa may form outcrops at higher elevations, but most of the area is covered with material weathered from deep volcanic ash. Areas of volcanic sand and gravel alluvium exist. Average annual precipitation ranges from 20 to 75 inches (500 to 1875 millimeters). Most of the rainfall occurs during kona storms from November through March. In some areas afternoon fog accumulation at higher elevations adds significant moisture to the soil by fog drip and also ameliorates evapotranspiration. Average annual air temperatures range from 50 to 71 degrees F (10 to 20 degrees C), with little seasonal variation. Strong winds are frequent in the saddle between Mauna Kea and Kohala volcanoes. The dominant soil order is Andisols with an isomesic soil temperature regime and ustic or udic soil moisture regime. Native vegetation consists of forests and rangelands that can include medium to tall statured forests, savannas, and grasslands.

Classification relationships

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

Ecological site concept

This ecological site is the koa/mamani forest exists on the mauka slopes of Mauna Kea, with the exception of the southwest-facing part of the mountain, and on the west-facing mauka slopes of Haleakala. It is on State lands, State Division of Hawaiian Homelands parcels, and some extensive private lands mauka of Waimea. The State lands are accessible along Mana Road. Most of this ecological site is open grassland used for livestock grazing. Remnants of the forest can be seen along Mana Road on the east-facing slope of Mauna Kea and on Puuhuluhulu, which is at the intersection of Saddle Road and Observatory Road.

This ecological site has not yet been correlated with soils on Haleakala on Maui; further field work is needed.

The central concept of the Isomesic-Cool Isothermic Forest is of well drained, shallow to deep Andisols formed in deposits of volcanic ash ranging from 5,000 to 300,000 years old. Annual air temperatures and rainfall create cool (isomesic to the cooler range of isothermic), seasonally dry (ustic to the drier range of udic) soil conditions. The tall tree overstory consists of koa (*Acacia koa*) and ohia lehua (Metrosideros polymorpha). The secondary tree overstory contains species that would form the overstory in drier forest types, such as mamani (Sophora chrysophylla), naio (Myoporum sandwicense), sandalwood (*Santalum paniculatum*), akoko (Chamaesyce olowaluana), mountain pilo (Coprosma montana), and kolea (Myrsine lanaiensis). Many species of native shrubs, vines, forbs, ferns, grasses, and sedges can be found in this ecological site.

Associated sites

VX159A01X500	**Well Drained Udic and Perudic Forest** F159AY500 Deep and Very Deep Volcanic Ash Forest is tall stature rain forest dominated by koa, ohia lehua, and hapuu bordering F160XY502 at lower elevations.

Similar sites

VX160X01X504	**Ustic-Dry Udic Forest** F160XY504 Ustic-Dry Udic Forest has a similar climate to F160XY502 but on younger soils and with different plant understory species.
VX161B01X503	**Ustic Isomesic Forest** F161BY503 Ustic Isomesic Forest is similar in plant species composition to F160XY502. F161BY503 is on Mauna Loa and Hualalai; soils are younger and often with organic rather than mineral parent materials.

Table 1. Dominant plant species

Tree	(1) *Acacia koa* (2) *Sophora chrysophylla*
Shrub	(1) *Dubautia*
Herbaceous	Not specified

Legacy ID

F160XY502HI

Physiographic features

This ecological site occurs on volcanic ash fields over lava flows on sloping mountainsides of shield volcanoes. Lava flows are aa (loose, cobbly) or pahoehoe (smooth, relatively unbroken). Volcanic ash fields range from moderately deep to deep on the underlying lava.

Table 2. Representative physiographic features

Landforms	(1) Shield volcano (2) Mountain slope
Flooding frequency	None
Ponding frequency	None
Elevation	1,052–2,438 m
Slope	6–20%
Water table depth	152 cm
Aspect	N, NE, E

Climatic features

There are no climate stations near this ecological site with complete data sets suitable for automatically filling the data boxes and charts below.

The estimates in the following text are based on modeled climate maps and incomplete and/or historic data sets from multiple stations compiled by NRCS Hawaii Soil Survey.

Average annual precipitation ranges from 20 to 80 inches (500 to 2000 mm). Most of the precipitation falls from November through April.

Average annual temperature ranges from 53 to 65 degrees F (12 to 19 degrees C).

Condensation of fog droplets onto trees and subsequent throughfall adds a significant amount of moisture to this plant community (Juvik and Nullet 1993).

Table 3. Representative climatic features

Frost-free period (average)	0 days
Freeze-free period (average)	0 days
Precipitation total (average)	0 mm

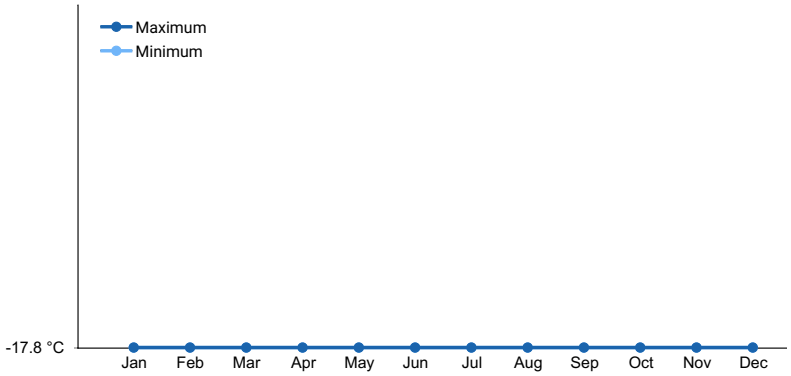

Figure 1. Monthly average minimum and maximum temperature

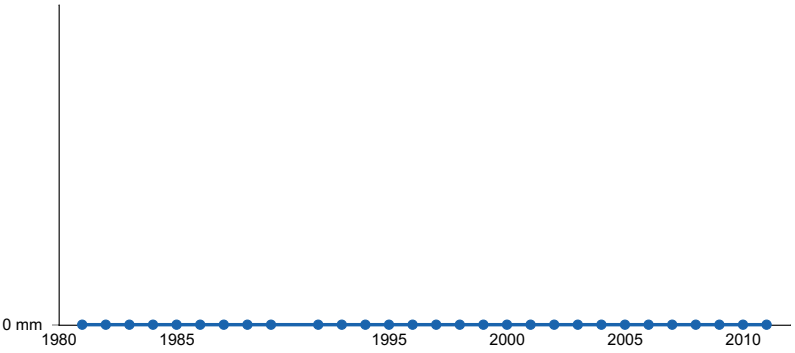

Figure 2. Annual precipitation pattern

Influencing water features

There are no water features influencing this site.

Soil features

Typical soils in this ecological site formed in shallow to deep, rapidly weathered volcanic ash deposited on aa or pahoehoe. Soil temperature regimes are isothermic to isomesic. Soil moisture regimes are ustic (soil moisture control section is dry in some or all parts for 90 or more cumulative days in normal years) to udic (in most years, not dry for as long as 90 cumulative 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).

Table 4. Representative soil features

Parent material	(1) Basaltic volcanic ash–basalt
Surface texture	(1) Medial silt loam (2) Very fine sandy loam
Family particle size	(1) Loamy
Drainage class	Well drained
Permeability class	Moderately rapid to rapid
Soil depth	51–152 cm
Surface fragment cover <=3"	0–1%
Surface fragment cover >3"	0–1%
Available water capacity (0-101.6cm)	5.08–33.02 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)	5.2–8.1
Subsurface fragment volume <=3" (Depth not specified)	0–20%
Subsurface fragment volume >3" (Depth not specified)	0–95%

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

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 windthrow of trees. Wildfires started by lightning sometimes affect 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 and animals, and wood harvesting. Higher elevation forests, such as this ecological site, would have been much less affected, but may have been affected by factors such as inadvertently introduced plant diseases and seed predation by the introduced Pacific rat (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.

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. 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, birds, reptiles, amphibians, invertebrates, plants, and microorganisms, have brought about dramatic changes to wild ecosystems in Hawaii. Much of the original forest of this ecological site has been cleared and planted with introduced grasses for livestock grazing, and the remaining native plant stands have been highly disturbed.

Most of the mountain sandalwood (*Santalum paniculatum*) was cut from this ecological site forests and shipped to China in the early 1800s. Most of the sandalwood had been harvested by the 1840s.

By the second quarter of the 19th Century, immense herds of livestock were present in the area. Throughout the middle and late 1800s, efforts at control of the introduced herbivores continued, but with only minimal success (Henke 1929). Currently, areas used by domestic livestock are fenced and managed for forage grasses.

A series of large wildfires swept through this ecological site in the early 20th century. These fires probably were carried by introduced grasses that had been established in the area.

Gorse (*Ulex europaeus*) was introduced intentionally to this ecological site early in the 20th century to function as a living fence. It has since expanded its range and density considerably and now forms a monoculture on large acreages.

State and transition model

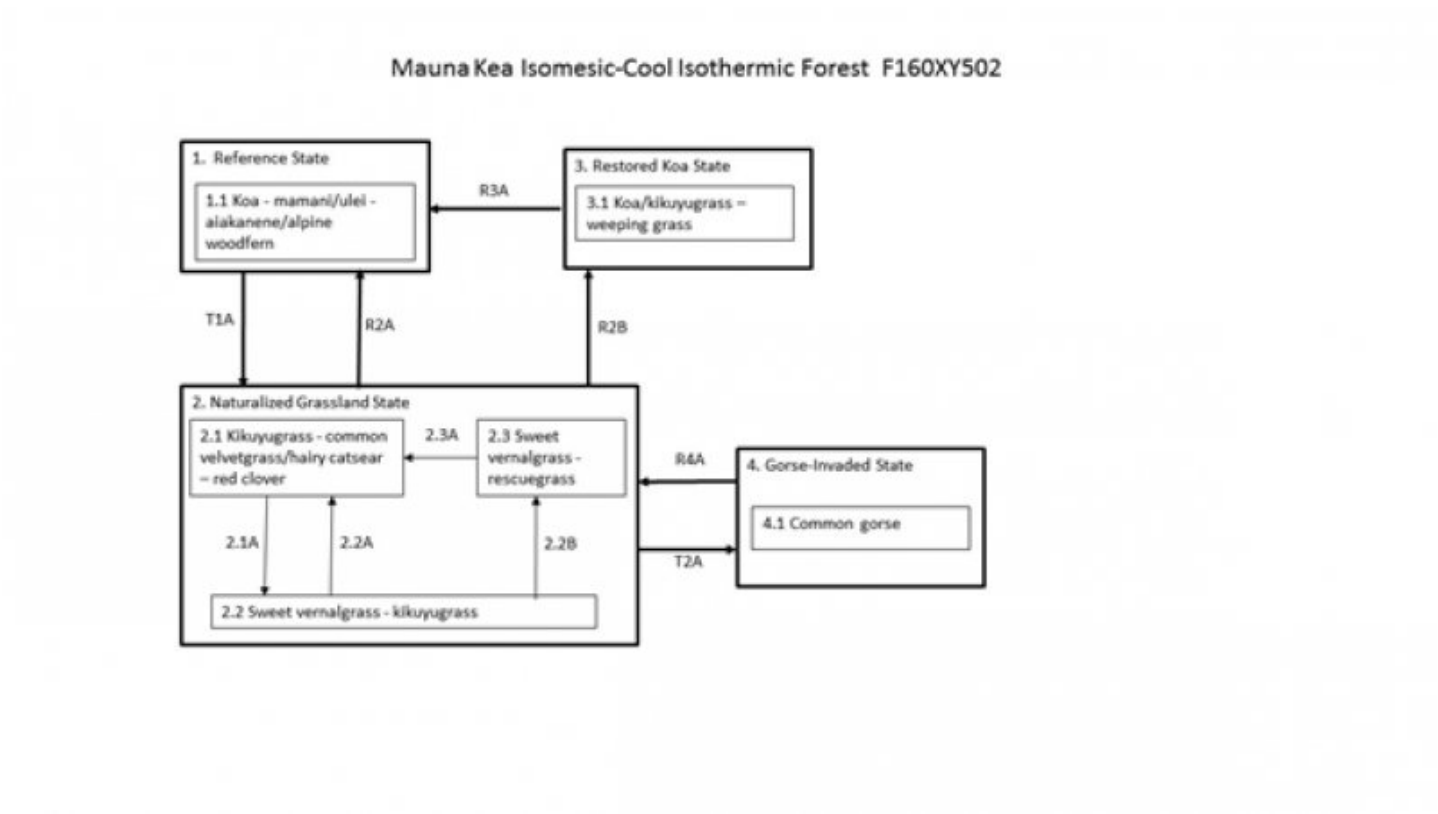

Figure 4. STM F160XY502

State 1
Reference State

This state consists of one community phase. Intact examples of this community phase no longer exist. Most of the forested areas have transitioned to State 2 Naturalized Grassland through mechanical clearing, long-term grazing, browsing, and trampling by ungulates, wood harvesting, competition from introduced plant species, and wildfires. In order to describe an approximation of the Reference State, it was necessary to use information collected from small stands, incomplete plant communities, and similar ecological sites on the island.

Community 1.1
Koa - mamani/`ulei - aiakanene/alpine woodfern

Figure 5. Reference community phase overstory. 6/25/08 D Clausnitzer generic photo

Figure 6. Midstory. 11/07/06 D Clausnitzer MU839

Figure 7. Understory. 11/07/06 D Clausnitzer MU839

This is forest with an open or closed upper canopy of koa (*Acacia koa*) trees up to 80 feet (24 meters) tall, a secondary canopy of multiple species 20 to 50 feet tall, and an understory of shrubs, vines, grasses, and forbs. These forests typically have standing live timber of 1000 to 2500 cubic feet per acre, with a representative value of about 1700 cubic feet per acre. These estimates represent recent measurements of standing live trees that are probably lower than the amounts present in the original, undisturbed forests.

Forest overstory. The overstory consists of koa and some ohia lehua (Metrosideros polymorpha) up to 80 feet (24 meters) tall.

Forest understory. The understory consists of an intermediate canopy 20 to 50 feet (6 to 15 meters) tall of mountain sandalwood (Santalum paniculatum), naio (Myoporum sandwicense), mamani (Sophora chrysophylla), akoko or alpine sandmat (Chamaesyce olowaluana), mountain pilo or alpine mirrorplant (Coprosma montana), kolea or Lanai colicwood (Myrsine lanaiensis), kolea lau nui (Myrsine lessertiana), and hoawa or cheesewood (Pittosporum spp.). Just below this canopy are tree-form aalii (Dodonaea viscosa) and naenae or Mauna Kea dubautia (Dubautia arborea). The lowest levels of the forest include about eight grass or grass-like species, nine forb species, five fern or fern ally species, 13 shrub species, five vine species, and seedlings and saplings of the overstory species.

Table 5. Soil surface cover

Tree basal cover	3-4%
Shrub/vine/liana basal cover	1-2%
Grass/grasslike basal cover	0.1-0.5%
Forb basal cover	0.0-0.1%
Non-vascular plants	0.5-1.0%
Biological crusts	0.5-1.0%

Litter	80-85%
Surface fragments >0.25" and <=3"	0.5-1.0%
Surface fragments >3"	0.5-1.0%
Bedrock	0%
Water	0%
Bare ground	0.5-1.0%

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)	–
Downed wood, coarse-small (3.00-8.99" diameter; 1,000-hour fuels)	2-3%
Downed wood, coarse-large (>9.00" diameter; 10,000-hour fuels)	1-1%
Tree snags** (hard***)	–
Tree snags** (soft***)	–
Tree snag count** (hard***)	5-7 per hectare
Tree snag count** (hard***)	2-5 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%	1-1%	1-1%
>0.15 <= 0.3	0%	1-2%	2-3%	1-2%
>0.3 <= 0.6	0-1%	5-7%	1-2%	2-3%
>0.6 <= 1.4	0-1%	5-7%	–	1-2%
>1.4 <= 4	5-10%	5-7%	–	–
>4 <= 12	25-30%	–	–	–
>12 <= 24	35-40%	–	–	–
>24 <= 37	1-2%	–	–	–
>37	–	–	–	–

State 2
Naturalized Grassland State

This state is comprised of three community phases. They are naturalized grasslands that may have an open canopy of remnant native trees. Trees in these pastures provide shade and protection from the elements to livestock. Where shade is dense, the growth of a weedy cool-season grass species can be favored. Very little tree regeneration occurs, so trees eventually die out. Community phase 2.1 is dominated by warm-season (C4) kikuyugrass (*Pennisetum clandestinum*) with a small admixture of cool-season (C3) forage grasses. C3 forage grasses increase with increasing elevation and decreasing grazing pressure. Cool-season meadow ricegrass, a less desirable forage species, may be abundant in shady areas under trees. Continuous grazing that does not allow favored forage species time to recover from defoliation results in community phase 2.2, which is dominated by lower value forage species but contains enough desired forage grasses to change back to 2.1 with prescribed grazing. Further continuous grazing leads to community phase 2.3, which is dominated by undesirable grass

species and weedy forbs.

Community 2.1
Kikuyugrass - common velvetgrass/hairy catsear - red clover

Figure 8. Kikuyu grassland with remnant native trees. 1/06/09 D Clausnitzer generic photo

Figure 9. Evidence of former koa forest. 7/18/08 D Clausnitzer generic photo

Figure 10. Pig damage to soil surface. 01/06/09 D Clausnitzer generic photo

The dominant grass species is kikuyugrass. Some cool-season perennial forage grasses are present along with forage legumes. All of the grasses and forbs are introduced species. Native koa and mamani trees may be present.

Forest overstory. Native koa (Acacia koa) and mamani (Sophora chrysophylla) trees may be present, along with dead and downed trees.

Forest understory. Kikuyugrass is by far the most abundant and productive forage grass. Cool-season perennial

forage grasses include common velvetgrass (Holcus lanatus), orchardgrass (Dactylis glomerata), perennial ryegrass (Lolium perenne), Italian ryegrass (Lolium multiflorum), and Kentucky bluegrass (Poa pratensis), and sweet vernalgrass (Anthoxanthum odoratum). Annual or short-lived perennial grasses, including tufted lovegrass (Eragrostis pectinacea), rescuegrass (Bromus catharticus), and brome fescue (Vulpia bromoides) are present. Three forage legumes, rabbitfoot clover (Trifolium arvense), red clover (Trifolium pretense), and white clover (Trifolium repens) are present in significant amounts.

Community 2.2
Sweet vernalgrass - kikuyugrass

Figure 12. Sweet vernalgrass and kikuyugrass with remnant mamani.
01/06/09 D Clausnitzer generic photo

This community phase has significant cover of grasses of relatively low forage value such as sweet vernalgrass, as well as increased cover of weedy forbs. Desirable forage legumes have been grazed out. Native koa and/or mamani trees may be present.

Forest overstory. Native koa (Acacia koa) and mamani (Sophora chrysophylla) trees may be present, along with dead and downed trees.

Forest understory. Percent cover of kikuyugrass, common velvetgrass, and orchardgrass is still significant but much reduced from community phase 3.1. The most abundant grass is sweet vernalgrass, which is a less desirable forage. The three clover species present in phase 3.1 are no longer present. Cover of weedy forbs has increased to around 20 percent.

Table 8. Soil surface cover

Tree basal cover	0.0-0.1%
Shrub/vine/liana basal cover	0%
Grass/grasslike basal cover	15-25%
Forb basal cover	1-2%
Non-vascular plants	0.1-1.0%
Biological crusts	0.1-1.0%
Litter	60-70%
Surface fragments >0.25" and <=3"	0.5-1.0%
Surface fragments >3"	0.5-1.0%
Bedrock	0%
Water	0%
Bare ground	5-10%

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

Height Above Ground (M)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.15	–	0%	0%	0-1%
>0.15 <= 0.3	–	0%	1-1%	1-2%
>0.3 <= 0.6	–	1-1%	80-90%	15-25%
>0.6 <= 1.4	–	0%	1-1%	1-1%
>1.4 <= 4	–	–	–	–
>4 <= 12	1-5%	–	–	–
>12 <= 24	1-25%	–	–	–
>24 <= 37	–	–	–	–
>37	–	–	–	–

Community 2.3
Sweet vernalgrass - rescuegrass

Figure 13. Degraded grassland. 07/18/08 D Clausnitzer generic photo

This community phase is dominated by undesirable grasses and weedy forbs. Abundance of desirable forages has declined to a level that requires more than just prescribed grazing to bring back high forage productivity.

Forest overstory. Native koa (Acacia koa) and mamani (Sophora chrysophylla) trees may be present, along with

dead and downed trees.

Forest understory. Sweet vernalgrass is the most abundant grass species, and rescuegrass has increased to significant abundance. Common velvetgrass and orchardgrass are present but low in cover. Annual grasses and weedy forbs make up a large part of total plant cover. The extent of bare soil is around 20 percent.

Table 11. Soil surface cover

Tree basal cover	0%
Shrub/vine/liana basal cover	0%
Grass/grasslike basal cover	25-30%
Forb basal cover	3-5%
Non-vascular plants	0.0-0.5%
Biological crusts	0.0-0.5%
Litter	50-60%
Surface fragments >0.25" and <=3"	0.5-1.0%
Surface fragments >3"	0.5-1.0%
Bedrock	0%
Water	0%
Bare ground	10-20%

Table 12. Canopy structure (% cover)

Height Above Ground (M)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.15	–	0%	1-2%	0-1%
>0.15 <= 0.3	–	0%	1-2%	0-1%
>0.3 <= 0.6	–	0%	60-70%	40-50%
>0.6 <= 1.4	–	0%	1-2%	1-1%
>1.4 <= 4	–	–	–	–
>4 <= 12	–	–	–	–
>12 <= 24	–	–	–	–
>24 <= 37	0-1%	–	–	–
>37	0-1%	–	–	–

Pathway 2.1A
Community 2.1 to 2.2

Kikuyugrass - common velvetgrass/hairy catsear - red clover

Sweet vernalgrass - kikuyugrass

Community phase 2.1 changes to community phase 2.2 by continuous grazing that weakens preferred grasses and legumes in relation to less desirable forage species such as sweet vernalgrass and rescuegrass. Weedy forbs also increase under these conditions.

Pathway 2.2A

Community 2.2 to 2.1

Sweet vernalgrass - kikuyugrass

Kikuyugrass - common velvetgrass/hairy catsear - red clover

This community phase can change to phase 2.1 by prescribed grazing. A prescribed grazing plan provides for intensive but temporary grazing of pastures that ensures that cattle consume some low-value forage species along with preferred forages and allows preferred forages time to recover from defoliation. The grazing plan may require splitting the herd, creating additional water sources, and creating multiple pastures by cross-fencing.

Pathway 2.2B
Community 2.2 to 2.3

Sweet vernalgrass - kikuyugrass

Sweet vernalgrass - rescuegrass

This community phase changes to phase 2.1 by continuous grazing that further weakens preferred grasses and legumes in relation to less desirable forage species such as sweet vernalgrass. Weedy forbs also increase under these conditions.

Pathway 2.3A
Community 2.3 to 2.1

Sweet vernalgrass - rescuegrass

Kikuyugrass - common velvetgrass/hairy catsear - red clover

This community phase can be changed to phase 2.1 by a combination of herbicidal weed control, prescribed grazing, and replanting desirable forage species.

State 3
Restored Koa State

This state has one plant community consisting of a dense stand of small to medium stature koa (*Acacia koa*) trees that have resprouted from the soil seed bank or been planted in grassland. There may or may not be large remnant native trees present. This state may be intended for eventual harvest, an intermediate step to restoration to the Reference State, or for silvopasture.

Community 3.1
Koa/kikuyugrass - weeping grass

Figure 14. Dense koa regrowth. 01/06/09 D Clausnitzer generic photo

Koa seeds may remain viable in the soil for decades and can be induced to germinate by scarifying or scraping the soil surface with a bulldozer. If mature koa trees are present, suckers from their roots can quickly grow into spaces with sufficient sunlight. As the tree canopy closes, forage grasses are usually replaced by meadow ricegrass, which remains abundant unless killed by herbicide or suppressed by shadier conditions and heavy tree litter. Other native plant species will begin to grow in the understory if a seed source is nearby. As dense koa stands grow, all the trees may become stunted unless the stand is thinned.

Forest overstory. The overstory consists entirely of even-aged koa trees. Some older, larger remnant koa specimens may be present.

Forest understory. The understory may contain some native plants that opportunistically reenter the site. These include the tree mamani (Sophora chrysophylla), the shrubs aalii (Dodonaea viscosa) and pukiawe (Styphelia tameiameiae), the vines akala (Rubus argutus) and huehue (Cocculus orbiculatus), and the ferns io nui or alpine woodfern (Dryopteris wallichiana), western brackenfern Pteridium aquilinum), and oali or Cretan brake (Pteris cretica).

Introduced species in the understory are dominated by kikuyugrass and/or meadow ricegrass. Banana poka (Passiflora mollissima) may be present; it can smother tree canopies. A number of weedy forbs are usually present.

Table 13. Soil surface cover

Tree basal cover	1-2%
Shrub/vine/liana basal cover	0%
Grass/grasslike basal cover	30-40%
Forb basal cover	0%
Non-vascular plants	0.1-1.0%
Biological crusts	0%
Litter	50-60%
Surface fragments >0.25" and <=3"	0.1-1.0%
Surface fragments >3"	0.1-1.0%
Bedrock	0%
Water	0%
Bare ground	0-1%

Table 14. Canopy structure (% cover)

Height Above Ground (M)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.15	0%	0%	1-2%	1-1%
>0.15 <= 0.3	0%	0-1%	25-30%	1-2%
>0.3 <= 0.6	0%	1-1%	35-40%	3-5%
>0.6 <= 1.4	0-1%	1-1%	–	1-1%
>1.4 <= 4	3-5%	–	–	–
>4 <= 12	55-65%	–	–	–
>12 <= 24	–	–	–	–
>24 <= 37	–	–	–	–
>37	–	–	–	–

State 4
Gorse-Invaded State

This state has one community consisting of a dense stand of common gorse (*Ulex europaeus*). Scattered grasses and forbs are typically present in small numbers. Scattered, tall koa trees persist within these stands but are unable to reproduce. These sites are essentially wasteland. Gorse is extremely competitive with other vegetation, and it has long, sharp thorns that deter most browsing animals. The seeds are spread widely by birds. This species was introduced to Hawaii in the early 20th century to create living fences for livestock.

Community 4.1
Common gorse

Figure 15. Gorse stand with remnant koa trees near Hakalau. 06/25/08 D Clausnitzer generic photo

Figure 16. Solid gorse stand near Hakalau. 06/25/08 D Clausnitzer generic photo

Gorse forms a deep, dense, impenetrable thicket that largely excludes all other plant species.

Forest overstory. A few remnant koa (Acacia koa) trees may be present emerging from the gorse thicket.

Forest understory. A few small introduced forb and grass species exist where the gorse has not totally occupied the ground and canopy. These include fireweed or Madagascar ragwort (Senecio madagascariensis), narrowleaf plantain (Plantago lanceolata), common mullein (Verbascum thapsus), hairy catsear (Hypochaeris radicata), Chilean evening primrose (Oenothera stricta), common velvetgrass (Holcus lanatus), orchardgrass (Dactylis glomerata), rescuegrass (Bromus catharticus), sweet vernalgrass (Anthoxanthum odoratum), brome fescue (Vulpia bromoides), annual bluegrass (Poa annua), and kikuyugrass (Pennisetum clandestinum).

Table 15. Soil surface cover

Tree basal cover	0%
Shrub/vine/liana basal cover	3-4%
Grass/grasslike basal cover	0.0-0.5%
Forb basal cover	0%
Non-vascular plants	0-1%
Biological crusts	0-1%
Litter	65-75%
Surface fragments >0.25" and <=3"	0.1-1.0%
Surface fragments >3"	0.1-1.0%
Bedrock	0%
Water	0%
Bare ground	10-15%

Table 16. 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)	–
Downed wood, coarse-large (>9.00" diameter; 10,000-hour fuels)	–
Tree snags** (hard***)	–
Tree snags** (soft***)	–

Tree snag count** (hard***)	0 per hectare
Tree snag count** (hard***)	0 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 17. Canopy structure (% cover)

Height Above Ground (M)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.15	–	0%	1-2%	0%
>0.15 <= 0.3	–	0%	3-5%	0-1%
>0.3 <= 0.6	–	0-1%	1-2%	0-1%
>0.6 <= 1.4	–	5-10%	0-1%	0-1%
>1.4 <= 4	–	75-85%	–	–
>4 <= 12	0%	–	–	–
>12 <= 24	0-1%	–	–	–
>24 <= 37	–	–	–	–
>37	–	–	–	–

Transition T1A
State 1 to 2

This state will transition to State 2 Naturalized Grassland by removing the native understory, either by fire, machinery, or, more gradually, by continuous disturbance by ungulates. Forage grasses are then established by sprigging or seeding.

Restoration pathway R2A
State 2 to 1

A facsimile of State 1 Reference may be restored directly from State 2. Weed control must be applied to grassland species and the many opportunistic plant species that invade the site. Weed control will be a perpetual process to maintain the site even after a canopy of native trees and shrubs has developed. All ungulates must be excluded from the restoration site by fences and hunting. Domestic ungulates would be useful to manage vegetation outside the restoration site perimeter. Extensive planting of native species would follow. Koa is the key species for restoration. It can be replanted, and in some cases it can be restored by scarifying the soil with heavy equipment if a sufficient seed bank remains in the soil. As an overstory canopy develops, the increased shade will cause a shift from warm-season kikuyugrass to cool-season, shade-tolerant meadow ricegrass (*Microlaena stipoides*). Meadow ricegrass can be almost as dense and detrimental to establishment of native plants as kikuyugrass. It may be possible to partially suppress meadow ricegrass by planting native shrubs that produce denser shade near the ground and litter that covers the grass, although herbicides will be more effective.

Restoration pathway R2B
State 2 to 3

This state can be restored to State 3 Restored Koa either with the goal of creating stands of harvestable koa, creating a silvopastures, or as an intermediate step to State 1 Reference State. Koa trees can rapidly form a dense stand on these sites from seed bank germination stimulated by mechanical ground scarification, root suckering from remnant koa, and/or replanting. Herbicidal control of unwanted vegetation, including forage grasses, is necessary to reduce competition with tree seedlings. Ungulates must be excluded for at least five to seven years to allow koa saplings to grow large enough to withstand the presence of animals.

Transition T2A
State 2 to 4

Gorse (*Ulex europaeus*) rapidly invades pastures when a seed source is nearby and eventually forms impenetrable thickets with very little understory. Inspection of grasslands for gorse seedlings and treatment with herbicides is necessary to prevent this.

Restoration pathway R3A
State 3 to 1

This state can be restored to State 1 Reference. Herbicides will be necessary to eliminate banana poka and other weeds that invade the site, as well as to reduce grass cover. Ungulates must be excluded from the site. Reintroduction of native understory plants is likely be necessary. Very dense stands of koa will benefit from thinning.

Restoration pathway R4A
State 4 to 2

It may be possible to restore this state to State 2 Naturalized Grassland. Multiple herbicide applications followed by removal of dead brush and reestablishment of forage grasses is necessary. However, the gorse seed bank in the soil can persist for decades, making continual control necessary.

Additional community tables

Table 18. Community 1.1 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)	Diameter (Cm)	Basal Area (Square M/Hectare)
Tree							
koa	ACKO	*Acacia koa*	Native	12.2–24.4	30–40	50.8–221	–
mamani	SOCH	*Sophora chrysophylla*	Native	4–9.1	15–20	–	–
mountain sandalwood	SAPA7	*Santalum paniculatum*	Native	4–12.2	5–10	–	–
naio	MYSA	*Myoporum sandwicense*	Native	4–9.1	5–7	–	–
Lanai colicwood	MYLA3	*Myrsine lanaiensis*	Native	4–9.1	3–5	–	–
alpine mirrorplant	COMO3	*Coprosma montana*	Native	4–10.7	3–5	–	–
kolea lau nui	MYLE2	*Myrsine lessertiana*	Native	4–9.1	1–2	–	–
koa	ACKO	*Acacia koa*	Native	24.4–27.4	1–2	–	–
alpine sandmat	CHOL3	*Chamaesyce olowaluana*	Native	4–7.6	0.5–1	–	–
Mauna Kea dubautia	DUAR	*Dubautia arborea*	Native	4–4.9	0.5–1	–	–
Florida hopbush	DOVI	*Dodonaea viscosa*	Native	4–6.1	0.5–1	–	–
cheesewood	PITTO	*Pittosporum*	Native	4–10.7	0.5–1	–	–
mountain sandalwood	SAPA7	*Santalum paniculatum*	Native	12.2–15.2	0–1	–	–
koa	ACKO	*Acacia koa*	Native	4–12.2	0.5–1	–	–
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	4–12.2	0–0.1	–	–
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	12.2–18.3	0–0.1	–	–

Table 19. Community 1.1 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
alpine hairgrass	DENU6	*Deschampsia nubigena*	Native	0.3–0.6	1–2
mountain lovegrass	ERLE3	*Eragrostis leptophylla*	Native	0.3–0.6	0–1
parkland panicgrass	PATE6	*Panicum tenuifolium*	Native	0.3–0.6	0–1
Oahu sedge	CAWA	*Carex wahuensis*	Native	0.2–0.3	0.1–1
Hawai'i woodrush	LUHA2	*Luzula hawaiiensis*	Native	0.2–0.3	0–1
pili uka	TRGL3	*Trisetum glomeratum*	Native	0.3–0.6	0–1
Hawai'i bentgrass	AGSA3	*Agrostis sandwicensis*	Native	0.3–0.6	0–1
brown sedge	CASU6	*Carex subfusca*	Native	0.2–0.3	0–0.5
Forb/Herb					
viper beggarticks	BICA2	*Bidens campylotheca*	Native	0.6–1.5	1–2
Sandwich beach strawberry	FRCHS2	*Fragaria chiloensis ssp. sandwicensis*	Native	0.1–0.2	0.1–0.5
Hawai'ian buttercup	RAHA2	*Ranunculus hawaiensis*	Native	0.3–0.9	0.1–0.5
Trans-Pecos cliffbrake	PETE2	*Pellaea ternifolia*	Native	0.1–0.2	0–0.1
Hawai'i stingingnettle	HESA5	*Hesperocnide sandwicensis*	Native	0.3–0.6	0–0.1
Kaumahana	KOCO	*Korthalsella complanata*	Native	0.1–0.2	0–0.1
Hawai'i korthal mistletoe	KOCY	*Korthalsella cylindrica*	Native	0.1–0.2	0–0.1
Hawai'i pokeweed	PHSA2	*Phytolacca sandwicensis*	Native	0.6–1.2	0–0.1
'ena'ena	PSSA8	*Pseudognaphalium sandwicensium*	Native	0.2–0.6	0–0.1
Fern/fern ally					
alpine woodfern	DRWA	*Dryopteris wallichiana*	Native	0.3–0.6	0.1–1
western brackenfern	PTAQ	*Pteridium aquilinum*	Native	0.3–0.6	0–1
Cretan brake	PTCR2	*Pteris cretica*	Native	0.1–0.2	0–0.1
maidenhair spleenwort	ASTR2	*Asplenium trichomanes*	Native	0.1–0.2	0–0.1
black spleenwort	ASAD	*Asplenium adiantum-nigrum*	Native	0.2–0.3	0–0.1
Shrub/Subshrub					
Hawai'i hawthorn	OSAN	*Osteomeles anthyllidifolia*	Native	0.6–2.4	5–10
Florida hopbush	DOVI	*Dodonaea viscosa*	Native	0.6–4	3–5
pukiawe	STTA	*Styphelia tameiameiae*	Native	0.6–1.8	3–5
'aiakanene	COER3	*Coprosma ernodeoides*	Native	0.2–0.6	3–5
Mauna Loa beggarticks	BIME	*Bidens menziesii*	Native	0.6–1.8	1–2
yellow ʻilima	SIFA	*Sida fallax*	–	0.6–1.2	1–2
ohelo 'ai	VARE	*Vaccinium reticulatum*	Native	0.6–0.9	1–2
pukamole	LYMA3	*Lythrum maritimum*	Native	0.6–0.9	0.5–1
pawale	RUGI	*Rumex giganteus*	Native	0.6–1.2	0.5–1
Mauna Kea dubautia	DUAR	*Dubautia arborea*	Native	0.6–4	0–1
lava dubautia	DUCI	*Dubautia ciliolata*	Native	0.6–1.8	0–1
shrubland dubautia	DULI	*Dubautia linearis*	Native	0.6–1.5	0–1
hillside clermontia	CLLI3	*Clermontia lindseyana*	Native	1.2–1.8	0–0.5
Tree					
mamani	SOCH	*Sophora chrysophylla*	Native	0.6–4	5–7

naio	MYSA	*Myoporum sandwicense*	Native	0.6–4	3–5
koa	ACKO	*Acacia koa*	Native	0.6–4	1–3
mountain sandalwood	SAPA7	*Santalum paniculatum*	Native	0.6–4	0.1–2
alpine mirrorplant	COMO3	*Coprosma montana*	Native	0.6–4	1–2
alpine sandmat	CHOL3	*Chamaesyce olowaluana*	Native	0.6–4	1–2
Lanai colicwood	MYLA3	*Myrsine lanaiensis*	Native	0.6–4	0–1
kolea lau nui	MYLE2	*Myrsine lessertiana*	Native	0.6–4	0–1
cheesewood	PITTO	*Pittosporum*	Native	0.6–4	0–0.1
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	0.6–4	0–0.1
Vine/Liana					
littleleaf stenogyne	STMI3	*Stenogyne microphylla*	Native	0.6–1.2	3–5
Hawai'i blackberry	RUHA	*Rubus hawaiensis*	Native	0.6–1.2	1–2
queen coralbead	COOR11	*Cocculus orbiculatus*	Native	0.2–1.2	0.5–1
lava bur cucumber	SIAN4	*Sicyos anunu*	Native	0.3–1.5	0.5–1

Table 20. Community 2.1 plant community composition

Group	Common Name	Symbol	Scientific Name	Annual Production (Kg/Hectare)	Foliar Cover (%)
Grass/Grasslike					
1	**Naturalized Warm Season Grasses**			3587–4259	
	kikuyugrass	PECL2	*Pennisetum clandestinum*	3587–4259	–
	smut grass	SPIN4	*Sporobolus indicus*	0–28	–
2	**Naturalized Cool Season Grasses**			0–224	
	sweet vernalgrass	ANOD	*Anthoxanthum odoratum*	0–140	–
	common velvetgrass	HOLA	*Holcus lanatus*	0–140	–
	orchardgrass	DAGL	*Dactylis glomerata*	0–140	–
	tufted lovegrass	ERPE	*Eragrostis pectinacea*	0–56	–
	perennial ryegrass	LOPE	*Lolium perenne*	0–56	–
	Kentucky bluegrass	POPR	*Poa pratensis*	0–56	–
	brome fescue	VUBR	*Vulpia bromoides*	0–56	–
	rescuegrass	BRCA6	*Bromus catharticus*	0–56	–
Forb					
3	**Naturalized Forbs**			0–224	
	hairy cat's ear	HYRA3	*Hypochaeris radicata*	0–140	–
	red clover	TRPR2	*Trifolium pratense*	0–140	–
	white clover	TRRE3	*Trifolium repens*	0–140	–
	suckling clover	TRDU2	*Trifolium dubium*	0–56	–
	common sheep sorrel	RUAC3	*Rumex acetosella*	0–28	–
	rabbitfoot clover	TRAR4	*Trifolium arvense*	0–28	–
Tree					
4	**Native Trees**			0–112	
	koa	ACKO	*Acacia koa*	0–112	–
	mamani	SOCH	*Sophora chrysophylla*	0–56	–

Table 21. Community 2.2 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)	Diameter (Cm)	Basal Area (Square M/Hectare)
Tree							
koa	ACKO	*Acacia koa*	Native	12.2–24.4	0–1	–	–
koa	ACKO	*Acacia koa*	Native	4–12.2	0–1	–	–
mamani	SOCH	*Sophora chrysophylla*	Native	4–6.1	0–0.1	–	–
mountain sandalwood	SAPA7	*Santalum paniculatum*	Native	6.1–12.2	–	–	–

Table 22. Community 2.2 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
sweet vernalgrass	ANOD	*Anthoxanthum odoratum*	Introduced	0.3–0.6	35–40
kikuyugrass	PECL2	*Pennisetum clandestinum*	Introduced	0.2–0.3	15–20
common velvetgrass	HOLA	*Holcus lanatus*	Introduced	0.3–0.6	10–15
orchardgrass	DAGL	*Dactylis glomerata*	Introduced	0.3–0.9	10–15
rescuegrass	BRCA6	*Bromus catharticus*	Introduced	0.6–0.9	3–5
brome fescue	VUBR	*Vulpia bromoides*	Introduced	0.1–0.2	0.5–1
annual fescue	VUMY	*Vulpia myuros*	Introduced	0.1–0.2	0.5–1
tufted lovegrass	ERPE	*Eragrostis pectinacea*	Introduced	0.3–0.6	0.5–1
annual bluegrass	POAN	*Poa annua*	Introduced	0.1–0.2	0.5–1
Forb/Herb					
Madagascar ragwort	SEMA15	*Senecio madagascariensis*	Introduced	0.2–0.3	5–10
narrowleaf plantain	PLLA	*Plantago lanceolata*	Introduced	0.1–0.2	3–5
hairy cat's ear	HYRA3	*Hypochaeris radicata*	Introduced	0.1–0.2	0.5–1
Peruvian groundcherry	PHPE4	*Physalis peruviana*	Introduced	0.3–0.6	0.1–0.5
common sheep sorrel	RUAC3	*Rumex acetosella*	Introduced	0.1–0.2	0.1–0.5
Chilean evening primrose	OEST	*Oenothera stricta*	Introduced	0.2–0.3	0.1–0.5
common mullein	VETH	*Verbascum thapsus*	Introduced	0.6–0.9	0.1–0.5
bull thistle	CIVU	*Cirsium vulgare*	Introduced	0.3–0.9	0–0.1
Shrub/Subshrub					
Florida hopbush	DOVI	*Dodonaea viscosa*	Native	0.6–1.2	–
yellow ʻilima	SIFA	*Sida fallax*	Native	0.3–0.9	–

Table 23. Community 2.3 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)	Diameter (Cm)	Basal Area (Square M/Hectare)
Tree							
koa	ACKO	*Acacia koa*	Native	12.2–24.4	0–1	–	–
koa	ACKO	*Acacia koa*	Native	4–12.2	0–1	–	–

Table 24. Community 2.3 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
sweet vernalgrass	ANOD	*Anthoxanthum odoratum*	Introduced	0.3–0.6	45–55
rescuegrass	BRCA6	*Bromus catharticus*	Introduced	0.6–0.9	10–15
kikuyugrass	PECL2	*Pennisetum clandestinum*	Introduced	0.2–0.3	3–5
common velvetgrass	HOLA	*Holcus lanatus*	Introduced	0.3–0.6	3–5
orchardgrass	DAGL	*Dactylis glomerata*	Introduced	0.3–0.6	0.5–1
Bermudagrass	CYDA	*Cynodon dactylon*	Introduced	0–0.1	0.5–1
Cuming's lovegrass	ERCU5	*Eragrostis cumingii*	Introduced	0.3–0.6	0.5–1
rose Natal grass	MERE9	*Melinis repens*	Introduced	0.3–0.6	0.5–1
brome fescue	VUBR	*Vulpia bromoides*	Introduced	0.2–0.3	0.5–1
annual fescue	VUMY	*Vulpia myuros*	Introduced	0.2–0.3	0.5–1
annual bluegrass	POAN	*Poa annua*	Introduced	0.1–0.2	0.5–1
Forb/Herb					
Madagascar ragwort	SEMA15	*Senecio madagascariensis*	Introduced	0.2–0.3	30–40
narrowleaf plantain	PLLA	*Plantago lanceolata*	Introduced	0.1–0.2	3–5
Australasian geranium	GEHO5	*Geranium homeanum*	Introduced	0.1–0.2	0.5–1
common yarrow	ACMI2	*Achillea millefolium*	Introduced	0.2–0.3	0.5–1
hairy beggarticks	BIPI	*Bidens pilosa*	Introduced	0.2–0.3	0.5–1
black mustard	BRNI	*Brassica nigra*	Introduced	0.3–0.6	0.5–1
cultivated radish	RASA2	*Raphanus sativus*	Introduced	0.3–0.6	0.5–1
smooth hawksbeard	CRCA3	*Crepis capillaris*	Introduced	0.3–0.6	0.5–1
woodland ragwort	SESY	*Senecio sylvaticus*	Introduced	0.2–0.3	0.5–1
old-man-in-the-Spring	SEVU	*Senecio vulgaris*	Introduced	0.3–0.6	0.5–1
hairy cat's ear	HYRA3	*Hypochaeris radicata*	Introduced	0.1–0.2	0.5–1
telegraphweed	HEGR7	*Heterotheca grandiflora*	Introduced	0.3–0.6	0.5–1
Chilean evening primrose	OEST	*Oenothera stricta*	Introduced	0.2–0.3	0.5–1
sweet fennel	FOVU	*Foeniculum vulgare*	Introduced	0.3–0.6	0.5–1
golden crownbeard	VEEN	*Verbesina encelioides*	Introduced	0.3–0.6	0.5–1
common mullein	VETH	*Verbascum thapsus*	Introduced	0.6–0.9	0.5–1
bull thistle	CIVU	*Cirsium vulgare*	Introduced	0.3–0.6	–
Shrub/Subshrub					
Florida hopbush	DOVI	*Dodonaea viscosa*	Native	0.3–0.9	–
yellow ‘ilima	SIFA	*Sida fallax*	Native	0.3–0.6	–

Table 25. Community 3.1 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)	Diameter (Cm)	Basal Area (Square M/Hectare)
Tree							
koa	ACKO	*Acacia koa*	Native	4–7.6	55–65	5.1–10.2	–
koa	ACKO	*Acacia koa*	Native	0.6–4	3–5	–	–

Table 26. Community 3.1 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
weeping grass	MIST	*Microlaena stipoides*	Introduced	0.3–0.5	35–45
kikuyugrass	PECL2	*Pennisetum clandestinum*	Introduced	0.2–0.3	25–35
sweet vernalgrass	ANOD	*Anthoxanthum odoratum*	Introduced	0.3–0.6	1–2
common velvetgrass	HOLA	*Holcus lanatus*	Introduced	0.3–0.6	1–2
Forb/Herb					
spreading snakeroot	AGRI2	*Ageratina riparia*	Introduced	0.3–0.6	0.5–1
Australasian geranium	GEHO5	*Geranium homeanum*	Introduced	0.2–0.3	0.5–1
narrowleaf plantain	PLLA	*Plantago lanceolata*	Introduced	0.1–0.2	0.5–1
Peruvian groundcherry	PHPE4	*Physalis peruviana*	Introduced	0.6–0.9	0.5–1
Jerusalem cherry	SOPS	*Solanum pseudocapsicum*	Introduced	0.6–0.9	0.5–1
Fern/fern ally					
western brackenfern	PTAQ	*Pteridium aquilinum*	Native	0.3–0.6	3–5
alpine woodfern	DRWA	*Dryopteris wallichiana*	Native	0.3–0.6	0.5–1
Cretan brake	PTCR2	*Pteris cretica*	Native	0.1–0.2	0.1–0.5
Shrub/Subshrub					
Florida hopbush	DOVI	*Dodonaea viscosa*	Native	0.3–1.2	0.5–1
pukiawe	STTA	*Styphelia tameiameiae*	Native	0.6–1.2	0.1–0.5
Tree					
mamani	SOCH	*Sophora chrysophylla*	–	1.5–4	0.1–0.5
Vine/Liana					
sawtooth blackberry	RUAR2	*Rubus argutus*	Introduced	0.6–1.2	0.1–1
queen coralbead	COOR11	*Cocculus orbiculatus*	Native	0.3–1.5	0.1–0.5

Table 27. Community 4.1 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)	Diameter (Cm)	Basal Area (Square M/Hectare)
Tree							
koa	ACKO	*Acacia koa*	Native	12.2–21.3	0–1	–	–

Table 28. Community 4.1 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (M)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
common velvetgrass	HOLA	*Holcus lanatus*	Introduced	0.3–0.6	0.5–1
kikuyugrass	PECL2	*Pennisetum clandestinum*	Introduced	0.2–0.3	0–0.5
orchardgrass	DAGL	*Dactylis glomerata*	Introduced	0.3–0.6	0–0.1
rescuegrass	BRCA6	*Bromus catharticus*	Introduced	0.3–0.6	0–0.1
sweet vernalgrass	ANOD	*Anthoxanthum odoratum*	Introduced	0.3–0.6	0–0.1
brome fescue	VUBR	*Vulpia bromoides*	Introduced	0.1–0.2	0–0.1
annual bluegrass	POAN	*Poa annua*	Introduced	0.1–0.2	0–0.1
Forb/Herb					
Chilean evening primrose	OEST	*Oenothera stricta*	Introduced	0.2–0.3	0–0.1
Madagascar ragwort	SEMA15	*Senecio madagascariensis*	Introduced	0.2–0.3	0–0.1
narrowleaf plantain	PLLA	*Plantago lanceolata*	Introduced	0.1–0.2	0–0.1
common mullein	VETH	*Verbascum thapsus*	Introduced	0.6–0.9	0–0.1
hairy cat's ear	HYRA3	*Hypochaeris radicata*	Introduced	0.1–0.2	0–0.1
Shrub/Subshrub					
common gorse	ULEU	*Ulex europaeus*	Introduced	1.2–4	75–85
common gorse	ULEU	*Ulex europaeus*	Introduced	0.6–1.2	5–10

Animal community

Native Wildlife
The Reference State of this ecological site can support a variety of native birds, including elepaio (Chasiempis sandwichensis bryani), amakihi (Hemignathus virens), apapane (Himatione sanguinea), and iiwi (Vestiaria coccinea). It also is home to the Hawaiian hoary bat or opeapea (Lasiurus cenarius semotus). These species may be encountered within community phases with native tree cover. Community phases that provide open grassland or savanna-like settings provide habitat for the native Hawaiian owl or pueo (Asio flammeus spp. sandwichensis) and the Hawaiian hawk or io (Buteo solitarius).

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), black francolin (Francolinus francolinus), and kalij pheasant (Lophura leucomelanos) are considered to be game birds.

Feral pigs and sheep are common. They provide hunting opportunities but are destructive to native vegetation. Public sport hunting typically does not have a major impact on their populations; exclusion by fences followed by intensive hunting and trapping within exclusion areas is necessary to eliminate feral animals.

Feral cats are present and are a threat to native bird species.

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 2.1. 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) 0.40-0.59 acre/AUM (note 3) 2.56-1.70 AUM/acre

High 0.59-0.78 acre/AUM 1.70-1.28 AUM/acre

Moderate 0.78-1.56 acre/AUM 1.28-0.64 AUM/acre

Low 1.56-+ acre/AUM 0.64-+ AUM/acre

(note 1) The Forage Value Rating System is not an ecological evaluation of community phase 2.1. 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 plant community is suitable for grazing by all kinds and classes of livestock, at any season, particularly cattle. However, this site is best utilized for grazing during the major plant growth period described in the “Climate” section. This site is suited for grazing by both cow-calf operations and stocker operations. However, sheep can be grazed on this site as well. This site is poorly suited to continuous year-long use if the condition of the plant community is to be maintained. Herbaceous forage can be deficient in protein during the drier months.

Hydrological functions

Most of the community phases of this ecological site are covered by vegetation and probably not prone to excessive soil erosion. Community phases 2.2 and especially 2.3 have high percentages of bare ground and are prone to excessive erosion.

Recreational uses

Hunting of introduced ungulates and game birds is the most common recreational use. Access by vehicle on gravel or dirt roads and on foot is easy in many areas.

Wood products

Mountain sandalwood was a valuable wood product in the past. There are no current wood products harvested from this ecological site. However, recent reestablishment of koa in limited areas may lead to valuable harvests in the future.

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.

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

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

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

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

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

Drainage class: The frequency 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° 49′ 23″
Longitude	155° 20′ 19″
General legal description	100 yards mauka of Mana Road, above Hakalau NWR, east face of Mauna Kea.
Location 2: Hawaii County, HI	
Latitude	19° 41′ 15″
Longitude	155° 27′ 56″
General legal description	Puuhuluhulu, next to old Saddle Road.

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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:**