USDA Natural Resources Conservation Service

Ecological site VX160X01X500
Deep Volcanic Ash Kipuka 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 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 small ecological site is a tall stature, diverse forest that exists almost entirely within the upper portion of Hawaii Volcanoes National Park, mauka of Kilauea Crater. Minor portions are found in the adjoining parts of Kapapala Ranch. The portions within HVNP are easily accessible by public roads, particularly Bird Park/Kipuka Puaulu.

The central concept of the Deep Volcanic Ash Kipuka Forest is of fertile, well drained, deep to very deep Andisols formed in deposits of volcanic ash ranging from 1,500 to 10,000 years old. Annual air temperatures and rainfall create transitionally warm to cool (isothermic to isomesic), moist to seasonally dry (udic to ustic) soil conditions conducive to plant growth for much of the year. Soils typically are only slightly acidic to neutral pH. The ecological site today centers on Kipuka Ki and Kipuka Puaulu in Hawaii Volcanoes National Park and on the same soils near these kipukas. These sites support tall-stature forest dominated by manele (wingleaf soapberry = *Sapindus saponaria*), which occurs on the Island of Hawaii only in this ecological site and at Puuwaawaa on the opposite side of the island. It is likely that manele is a remnant species that was protected from heavy ash falls and lava flows through time in the kipukas. The overstory also contains ohia lehua (Metrosideros polymorpha) and koa (Acacia koa). The secondary canopy contains tree species such as olopua (Nestegis sandwicensis), mamani (Sophora chrysophylla), and papala kepau (Pisonia brunoniana) that are common in transitional and cooler, drier areas. Other species occur here that are not found elsewhere or only at Puuwaawaa. Tree ferns (hapuu = Cibotium spp.) occur but are not abundant.

Associated sites

VX160X01X504	**Ustic-Dry Udic Forest** F160XY504 Ustic-Dry Udic Forest borders F160XY500 on younger, shallower soils formed in volcanic ash. Vegetation in F160XY504 has much lower species diversity.

Table 1. Dominant plant species

Tree	(1) *Sapindus saponaria* (2) *Acacia koa*
Shrub	Not specified
Herbaceous	Not specified

Legacy ID

F160XY500HI

Physiographic features

This ecological site occurs on lava flows on sloping mountainsides of shield volcanoes in kipukas containing deep deposits of volcanic ash.

A kipuka is an area that was not overrun by the most recent lava flow in a given area. The surface of a kipuka is older than that of the surrounding area and will contain older, more developed soils and vegetation communities.

Table 2. Representative physiographic features

Landforms	(1) Kipuka (2) Shield volcano (3) Lava flow
Flooding frequency	None
Ponding frequency	None
Elevation	3,300–4,600 ft
Slope	4–30%
Ponding depth	0 in
Water table depth	60 in
Aspect	SE, S

Climatic features

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.

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.

IMPORTANT NOTE:

This ecological site occurs in an area in which significant climate gradients can occur within very short differences. Although the climate station shown below is near this ecological site, the station data shows higher precipitation than actually occurs on the site. Average annual precipitation of this ecological site actually ranges from 55 to 75 inches (1375 to 1875 millimeters). Average annual temperature is about 60 degrees F (15 degrees C).

Table 3. Representative climatic features

Frost-free period (average)	365 days
Freeze-free period (average)	365 days
Precipitation total (average)	103 in

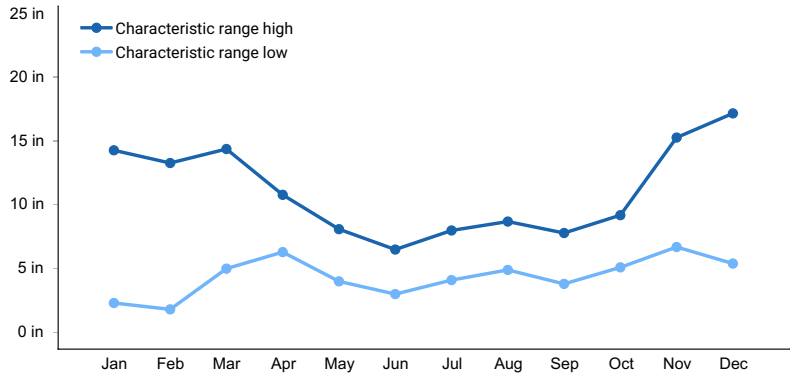


Figure 1. Monthly precipitation range

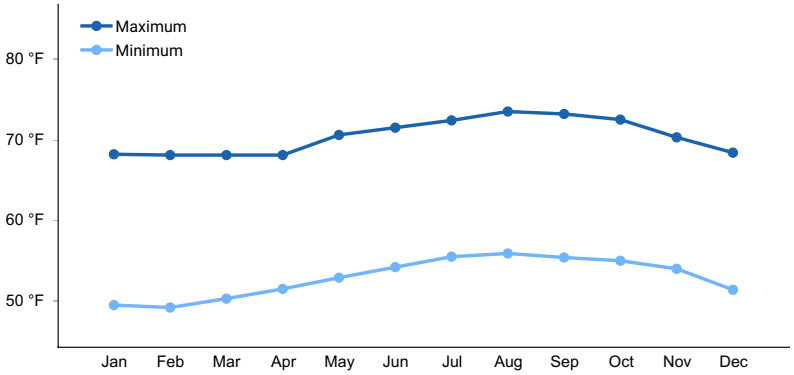


Figure 2. Monthly average minimum and maximum temperature

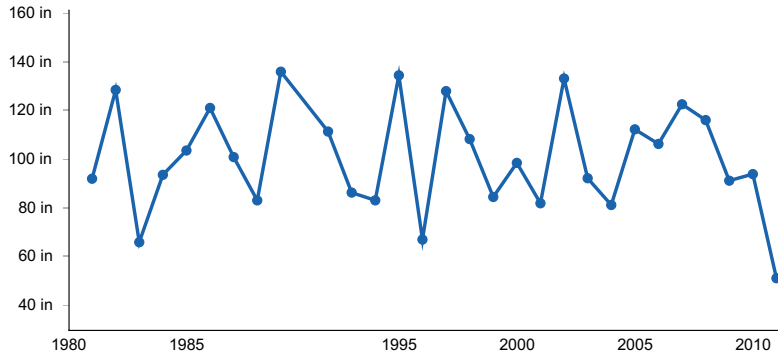


Figure 3. Annual precipitation pattern

Climate stations used

- (1) HAWAII VOL NP HQ 54 [USC00511303], Hawaii National Park, HI

Influencing water features

There are no water features influencing this site.

Soil features

Soils in this ecological site (ES) are deep and very deep, well drained soils that formed in basaltic volcanic ash. Soil temperature regimes are isomesic to isothermic. Soil moisture regimes are within the drier range of udic (in most years, not dry for as long as 90 cumulative days) and the moister range of 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).

Because these soils are deep to very deep, the type of underlying lava flow (aa or pahoehoe) has little or no effect on the use or management of the soils.

Table 4. Representative soil features

Parent material	(1) Basaltic volcanic ash–basalt
Surface texture	(1) Medial loam (2) Sandy loam
Family particle size	(1) Loamy
Drainage class	Well drained
Permeability class	Moderate to rapid
Soil depth	39–60 in
Surface fragment cover <=3"	0%
Surface fragment cover >3"	0–5%
Available water capacity (0-40in)	6–9 in
Calcium carbonate equivalent (0-40in)	0%
Electrical conductivity (0-40in)	0–2 mmhos/cm
Sodium adsorption ratio (0-40in)	0
Soil reaction (1:1 water) (0-40in)	5.6–7.3
Subsurface fragment volume <=3" (Depth not specified)	0–10%
Subsurface fragment volume >3" (Depth not specified)	0–35%

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, volcanic ash falls, and wind throw.

A lava flow obviously destroys all the vegetation it covers. Flows on this ecological site range from 2000 to over 10,000 years old and have since been covered with deep to very deep volcanic ash deposits in which soils have formed. Therefore, lava flows have not been a recent disturbance for this ecological site, either through direct burial of the surface or as a cause of wildfires.

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). The soils of this ecological site (Kapapala and Ki) both have buried B horizons, and Ki soils have multiple buried A horizons as well.

Wind throw of vegetation can occur during hurricanes or other high wind events. This disturbance may open the canopy periodically and create a mosaic of vegetation variations.

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. By 1851, records reported severe overstocking of pastures, lack of fences, and large numbers of feral livestock (Henke 1929).

Native forests were damaged by the extensive harvesting of tree ferns (hapuu) for pulu in the mid-1800s. Pulu is a soft fiber that covers the base of fronds of the hapuu. It was exported to the west coast of America to be used in pillows and mattresses.

Through the 20th and into the 21st centuries, increases in human populations with attendant land development, as well as accelerated introduction of non-native mammals, birds, reptiles, amphibians, invertebrates, plants, and

microorganisms, have brought about dramatic changes to wild ecosystems in Hawaii. This ecological site evolved without the presence of large mammals or the regular occurrence of fires. Most, and probably all, of the native reference community phase is currently disturbed by humans or has been restored approximately within the past 70 to 80 years.

Foraging by feral cattle and pigs or forest clearing and abandonment facilitate invasion by weeds. However, introduced weeds appear able to successfully invade native stands regardless of human or ungulate disturbances. Among the major weeds in forest areas are faya tree or firetree (*Morella faya*), weeping grass (*Microlaena stipoides*), and Sawtooth blackberry (*Rubus argutus*). Under improper management or abandonment, kikuyugrass grasslands are invaded by sawtooth blackberry, common guava (*Psidium guajava*), and unpalatable grasses such as broomsedge bluestem (*Andropogon virginicus*) and Colombian bluestem (*Schizachyrium condensatum*).

State and transition model

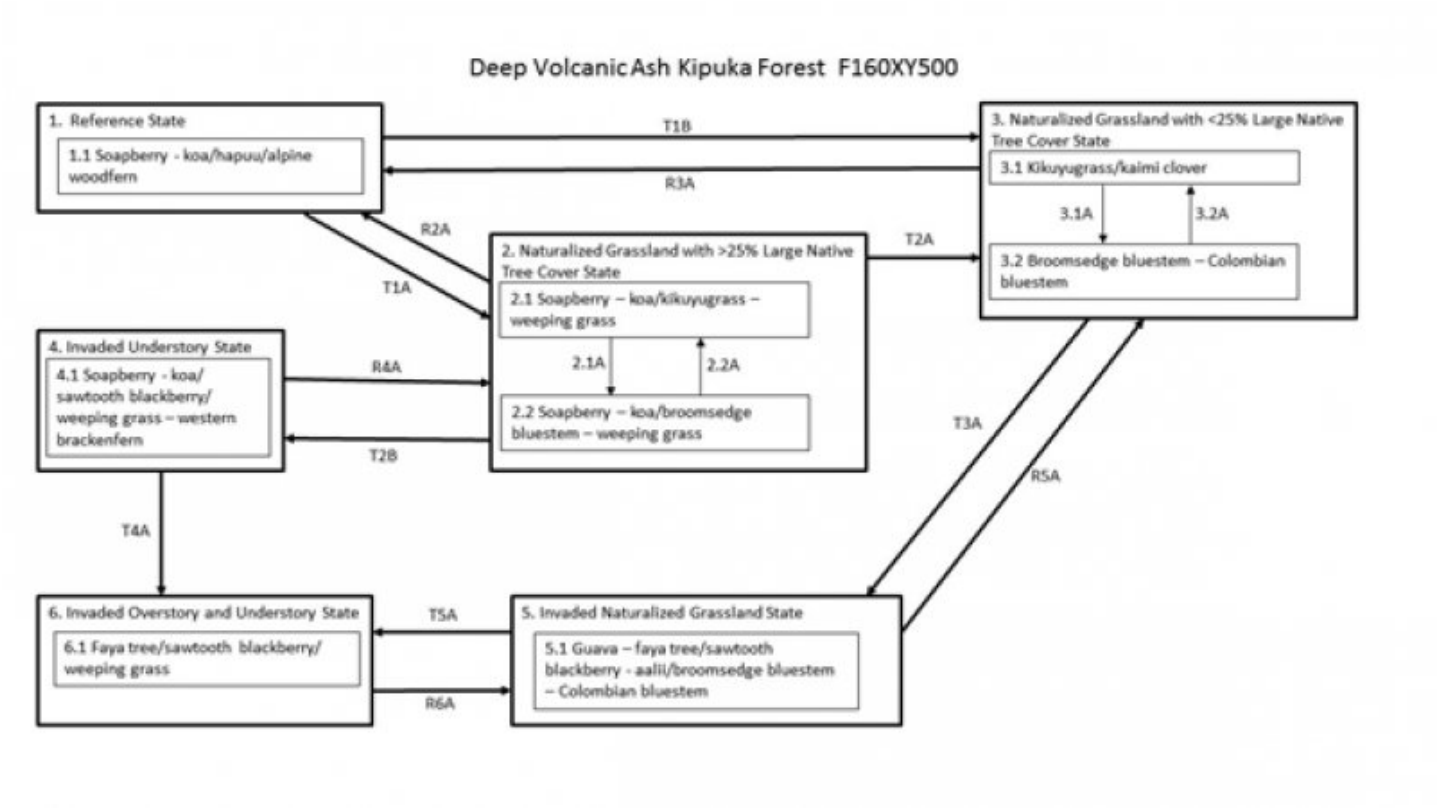


Figure 5. STM for F160XY500

State 1
Reference State

The Reference State consists of one plant community. Most or all current examples of this state had been disturbed by domestic animals foraging on introduced grasses in the forest understory until a change in management policy within Volcanoes National Park during the second quarter of the 20th century. This ecological site contains some native species, including the codominant tree wingleaf soapberry (*Sapindus saponaria*), that are extremely rare or nonexistent in other ecological sites on the Island of Hawaii. However, many of these species are found on Puuwaawaa cone in F161BY503 Ustic Isomesic Forest on the opposite side of the island.

Community 1.1
Soapberry - koa/hapu`u/alpine woodfern

Figure 6. Reference Community Phase 2/11/05 D Clausnitzer MU750

This community phase is a forest consisting of four canopy strata: a nearly closed upper canopy of ohia lehua, koa, and wingleaf soapberry about 80 feet (25 meters) tall, a secondary canopy of diverse tree species 30 to 40 feet (9 to 12 meters) tall, a sparse tree fern canopy 10 to 15 feet (3 to 4 meters) tall, and an understory of ferns and shrubs. This forests has standing live timber of 3000 to 6000 cubic feet per acre, with a representative value of about 5000 cubic feet per acre.

Forest overstory. The uppermost forest canopy consists of the codominant species ohia lehua, koa, and wingleaf soapberry.

Forest understory. Notable secondary canopy tree species are kopiko ula (Psychotria hawaiensis), naio (Myoporum sandwicense), mamani (Sophora chrysophylla), olopua (Nestegis sandwicensis), and pilo or woodland mirrorplant (Coprosma rhynchocarpa).

The sparse tree fern canopy apparently consists only of hapuu (Cibotium glaucum) at this time.

The lowest canopy stratum, which ranges in height from the ground to about 4.5 feet (1.5 meters), consists of seedlings and immature individuals of species in the taller strata, shrubs, forbs, vines (some prostrate, some climbing, some both), and ferns.

Table 5. Soil surface cover

Tree basal cover	3-5%
Shrub/vine/liana basal cover	0.0-0.1%
Grass/grasslike basal cover	0%
Forb basal cover	0.0-0.1%
Non-vascular plants	0.1-1.0%
Biological crusts	0%
Litter	75-85%
Surface fragments >0.25" and <=3"	0%
Surface fragments >3"	0%
Bedrock	0%
Water	0%
Bare ground	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)	1-5%
Downed wood, coarse-large (>9.00" diameter; 10,000-hour fuels)	1-5%
Tree snags** (hard***)	–
Tree snags** (soft***)	–
Tree snag count** (hard***)	1-2 per acre
Tree snag count** (hard***)	1-2 per acre

*** 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 (Ft)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.5	0%	0%	0%	0-1%
>0.5 <= 1	0%	0%	–	0-1%
>1 <= 2	0%	0%	–	0-1%
>2 <= 4.5	2-5%	0-1%	–	–
>4.5 <= 13	5-10%	0-1%	–	–
>13 <= 40	35-45%	–	–	–
>40 <= 80	55-65%	–	–	–
>80 <= 120	–	–	–	–
>120	–	–	–	–

State 2
Naturalized Grassland State with >25% Large Native Tree Cover State

This state is comprised of two community phases that have an open canopy of remnant native overstory tree species. Kikuyugrass (*Pennisetum clandestinum*) is the dominant grass, sometimes with pangolagrass (*Digitaria eriantha*). The shade produced by the tree canopy is sufficient to allow significant cover of cool-season (C3) meadow ricegrass or weeping grass (*Microlaena stipoides*) to grow. Trees in these pastures provide shade and protection from the elements to livestock. Very little regeneration of native trees is possible due to competition from grasses and damage by foraging livestock, leading to a transition to State 3, Naturalized Grassland with <25% Large Native Tree Cover, as mature trees die out. Continuous grazing that does not allow favored forage species time to recover from defoliation results in a change to Phase 2.2, which is dominated by lower value forage species but contains enough remnant kikuyugrass to allow for a shift back to Phase 2.1 with prescribed grazing. Longer-term continuous grazing leads to State 4, Invaded Understory.

Community 2.1
Soapberry - koa/kikuyugrass - weeping grass

Figure 7. Soapberry trees with kikuyugrass 11/23/05 D Clausnitzer MU631

Figure 8. Soapberry trees with kikuyugrass 11/23/05 D Clausnitzer MU631

The dominant grass species in this pasture type is kikuyugrass that has been planted as sprigs; pangolagrass has been planted on some sites. Kikuyugrass spreads by rhizomes and stolons, forming a dense, highly competitive stand. Other species may include naturalized leguminous herbs as well as a small admixture of cool-season grass species such as common velvetgrass (*Holcus lanatus*) and orchardgrass (*Dactylis glomerata*. Meadow ricegrass, a less desirable forage species, is common where trees shade the ground. Large soapberry, ohia, and koa trees are present.

Forest overstory. Large wingleaf soapberry, koa, and ohia lehua trees are present in varying proportions, forming an overstory of >25% canopy cover. Smaller trees sometimes present are mamani, naio, and sometimes overstory species that have managed to grow to a size at which they are not severely damaged by livestock.

Forest understory. This community phase is not forest, despite the automated default heading printed above this section, but rather a naturalized grassland that occurs where forests have been cleared.

Kikuyugrass is very competitive with other plants when properly managed and typically comprises most of the total forage production on a site. Common vetch (Vicia sativa), a desirable forage legume, can be maintained within kikuyugrass stands by careful grazing management.

Community 2.2
Soapberry - koa/broomsedge bluestem - weeping grass

Figure 10. Weedy grassland with tree overstory D Clausnitzer generic photo

This community phase is dominated by grass and grasslike species with lower forage value than kikuyugrass. Cattle can be maintained on these forages, but animal growth and vigor will be reduced. Also, the abundance of weedy species is high, and their stature, seed production potential, and wide distribution can lead to rapid increase unless management is improved.

Forest overstory. Large wingleaf soapberry, koa, and ohia lehua trees are present in varying proportions, forming an overstory of >25% canopy cover. Smaller trees sometimes present are mamani, naio, and sometimes overstory species that have managed to grow to a size at which they are not severely damaged by livestock.

Forest understory. Although kikuyugrass is still a major part of total grass production and cover, much less desirable grass species have increased, in particular weeping grass, broomsedge bluestem, Colombian bluestem, sweet vernalgrass (Anthoxanthum odoratum), and smutgrass (Sporobolus indicus). Desirable forage legumes have been grazed out. Weedy forbs have increased, and common guava (Psidium guajava) and sawtooth blackberry (Rubus argutus), while not yet abundant, are present in amounts that could rapidly increase.

Table 8. Soil surface cover

Tree basal cover	2-3%
Shrub/vine/liana basal cover	0.0-0.1%
Grass/grasslike basal cover	50-60%
Forb basal cover	1-2%
Non-vascular plants	0%
Biological crusts	0%
Litter	30-40%
Surface fragments >0.25" and <=3"	0%
Surface fragments >3"	0%
Bedrock	0%
Water	0%
Bare ground	3-5%

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)	0-0%
Downed wood, coarse-large (>9.00" diameter; 10,000-hour fuels)	0-0%

Tree snags** (hard***)	–
Tree snags** (soft***)	–
Tree snag count** (hard***)	0-1 per acre
Tree snag count** (hard***)	0-1 per acre

*** 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 (Ft)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.5	0%	0%	1-2%	1-2%
>0.5 <= 1	0%	0%	3-5%	3-5%
>1 <= 2	0-1%	0%	65-75%	1-2%
>2 <= 4.5	3-5%	0-1%	15-25%	1-2%
>4.5 <= 13	–	–	–	–
>13 <= 40	1-2%	–	–	–
>40 <= 80	25-45%	–	–	–
>80 <= 120	–	–	–	–
>120	–	–	–	–

Pathway 2.1A
Community 2.1 to 2.2

Soapberry - koa/kikuyugrass - weeping grass

Soapberry - koa/broomsedge bluestem - weeping grass

Community phase 2.1 changes to phase 2.2 by continuous grazing that weakens preferred kikuyugrass and legumes in relation to less desirable forage species such as broomsedge bluestem (*Andropogon virginicus*) and Colombian beardgrass (*Schizachyrium condensatum*). Undesirable forbs such as honohono (*Commelina diffusa*) and narrowleaf plantain (*Plantago lanceolata*) also increase.

Pathway 2.2A
Community 2.2 to 2.1

Soapberry - koa/broomsedge bluestem - weeping grass

Soapberry - koa/kikuyugrass - weeping grass

Community phase 2.2 can be reconverted to phase 2.1 by prescribed grazing. A prescribed grazing plan provides for intensive but temporary grazing 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. Invading broomsedge bluestem and Colombian beardgrass may be controlled by mowing their seed stalks before seed set and by liming to increase soil pH.

State 3
Naturalized Grassland State with <25% Large Native Tree Cover State

This state is comprised of two community phases in which native overstory tree canopy cover ranges from 0 to about 25%. Kikuyugrass (*Pennisetum clandestinum*) is the dominant grass, sometimes with pangolagrass (*Digitaria eriantha*). The shade produced by the tree canopy is insufficient to allow significant cover of cool-season (C3) meadow ricegrass or weeping grass (*Microlaena stipoides*) to grow. Continuous grazing that does not allow favored forage species time to recover from defoliation results in a change to phase 3.2, which is dominated by lower value forage species but contains enough remnant kikuyugrass to allow for a shift back to phase 3.1 with prescribed grazing. Longer-term continuous grazing leads to State 5, Invaded Naturalized Grassland.

Community 3.1
Kikuyugrass - kaimi clover

Figure 11. Kikuyu grassland D Clausnitzer generic photo

Figure 12. Scattered trees with kikuyugrass 11/24/05 D Clausnitzer MU631

The dominant grass species in this pasture type is kikuyugrass that has been planted as sprigs; pangolagrass has been planted on some sites. Kikuyugrass spreads by rhizomes and stolons, forming a dense, highly competitive stand. Other species may include naturalized leguminous herbs as well as a small admixture of cool-season grass species such as common velvetgrass (*Holcus lanatus*) and orchardgrass (*Dactylis glomerata*). Meadow ricegrass, a less desirable forage species, may occur where tree canopies create sufficient shade to favor this shade tolerant C3 grass.

Forest overstory. Large wingleaf soapberry, koa, and ohia lehua trees may be present in varying proportions, forming an overstory of 0 to about 25% canopy cover.

Forest understory. Kikuyugrass is very competitive with other plants when properly managed and typically comprises most of the total forage production on a site. Kaimi clover (Desmodium canum), a desirable forage legume, can be maintained within kikuyugrass stands by careful grazing management.

Community 3.2
Broomsedge bluestem - Colombian bluestem

Figure 14. Weedy grassland D Clausnitzer generic photo

This community phase is dominated by grass and grasslike species with lower forage value than kikuyugrass. Cattle can be maintained on these forages, but animal growth and vigor will be reduced. Also, the abundance of weedy species is high, and their stature, seed production potential, and wide distribution can lead to rapid increase unless management is improved.

Forest overstory. Large wingleaf soapberry, koa, and ohia lehua trees may be present in varying proportions, forming an overstory of 0 to about 25% canopy cover.

Forest understory. Although kikuyugrass is still a major part of total grass production and cover, much less desirable grass species have increased, in particular weeping grass, broomsedge bluestem, Colombian bluestem, sweet vernalgrass (Anthoxanthum odoratum), and smutgrass (Sporobolus indicus). Desirable forage legumes have been grazed out. Weedy forbs have increased, and common guava (Psidium guajava) and sawtooth blackberry (Rubus argutus), while not yet abundant, are present in amounts that could rapidly increase.

Table 11. Soil surface cover

Tree basal cover	0-1%
Shrub/vine/liana basal cover	0.0-0.1%
Grass/grasslike basal cover	40-50%
Forb basal cover	1-2%
Non-vascular plants	0%
Biological crusts	0%
Litter	40-50%
Surface fragments >0.25" and <=3"	0%
Surface fragments >3"	0%
Bedrock	0%
Water	0%
Bare ground	3-5%

Table 12. Canopy structure (% cover)

Height Above Ground (Ft)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.5	0%	0%	5-10%	3-5%
>0.5 <= 1	0%	0%	5-10%	3-5%
>1 <= 2	0-1%	1-2%	15-20%	1-2%
>2 <= 4.5	3-5%	1-2%	50-60%	–
>4.5 <= 13	–	–	–	–
>13 <= 40	–	–	–	–
>40 <= 80	–	–	–	–
>80 <= 120	–	–	–	–
>120	0-25%	–	–	–

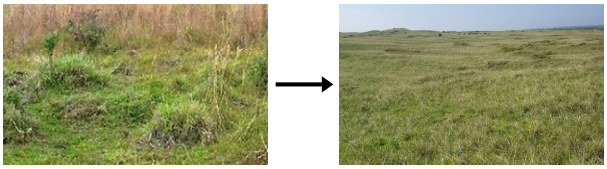
Pathway 3.1A
Community 3.1 to 3.2

Kikuyugrass - kaimi clover

Broomsedge bluestem - Colombian bluestem

Community phase 3.1 changes to phase 3.2 by continuous grazing that weakens preferred kikuyugrass and legumes in relation to less desirable forage species such as broomsedge bluestem (*Andropogon virginicus*) and Colombian beardgrass (*Schizachyrium condensatum*). Undesirable forbs such as honohono (*Commelina diffusa*) and narrowleaf plantain (*Plantago lanceolata*) also increase.

Pathway 3.2A
Community 3.2 to 3.1



Broomsedge bluestem - Colombian bluestem

Kikuyugrass - kaimi clover

Community phase 3.2 can be reconverted to phase 3.1 by prescribed grazing. A prescribed grazing plan provides for intensive but temporary grazing 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. Invading broomsedge bluestem and Colombian beardgrass may be controlled by mowing their seed stalks before seed set and by liming to increase soil pH.

State 4
Invaded Understory State

This state consists of one community phase. It arises by invasion by introduced species of intact native forest (the Reference State) or of native overstory stands from which the original understory has been cleared. Native species are unable to regenerate in the highly competitive understory of introduced plants and eventually die out. With time, introduced tree species will emerge to replace the native overstory trees. When this last step has occurred, the site will have transitioned to State 5, Invaded Overstory and Understory State. Disturbance of the soil and direct damage to native understory plants by introduced ungulates, particularly pigs and cattle, will speed the transition to this state by killing native plants and creating germination sites for introduced species. Restoration to the Reference

State or a facsimile of it is possible by fencing the site, removing all ungulates, applying herbicides, and replanting native species when needed. Intensity of restoration efforts will be dependent on the degree of invasion by introduced species and by the particular species that have invaded the site. Long term weed management and fence maintenance will be necessary.

Community 4.1
Soapberry - koa/sawtooth blackberry/weeping grass - western brackenfern

Figure 15. Invaded understory state 8/11/04 D Clausnitzer MU750

This community phase has an intact or diminished overstory of large wingleaf soapberry, ohia lehua, and/or koa trees with a dense understory of introduced shrubs, ferns, vines, grasses, and small trees.

Forest overstory. The overstory consists of wingleaf soapberry, ohia lehua, and koa. Smaller native species are somewhat diminished or nonexistent.

Forest understory. The only native species remaining in the lower canopy levels are a few aalii shrubs (Dodonaea viscosa). Some small native fern species may be present. The understory is usually dominated by sawtooth blackberry and lantana (Lantana camara).

Table 13. Soil surface cover

Tree basal cover	4-5%
Shrub/vine/liana basal cover	0.5-1.0%
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%
Litter	65-75%
Surface fragments >0.25" and <=3"	0%
Surface fragments >3"	0%
Bedrock	0%
Water	0%
Bare ground	0-1%

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)	1-1%
Downed wood, coarse-large (>9.00" diameter; 10,000-hour fuels)	1-1%
Tree snags** (hard***)	–
Tree snags** (soft***)	–
Tree snag count** (hard***)	0-1 per acre
Tree snag count** (hard***)	2-3 per acre

*** 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 (Ft)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.5	0%	0%	1-2%	3-5%
>0.5 <= 1	0%	0%	3-5%	3-5%
>1 <= 2	0%	0-1%	3-5%	3-5%
>2 <= 4.5	1-1%	20-60%	2-3%	0-1%
>4.5 <= 13	–	0-1%	–	–
>13 <= 40	0%	–	–	–
>40 <= 80	25-40%	–	–	–
>80 <= 120	–	–	–	–
>120	–	–	–	–

State 5
Invaded Naturalized Grassland State

This state consists of one community phase. It is a weedy grassland dominated by grass species with little or no forage value interspersed with shrubs and tree saplings. Tall stands of Colombian beardgrass and broomsedge bluestem present a high risk of wildfire. Desirable forage grasses such as kikuyugrass and pangolagrass may still be present in small amounts, but are no longer capable of regaining dominance of the site with prescribed grazing. Native aalii and pukiawe shrubs are able to grow up through the grass stands. Seedlings and saplings of invasive, introduced trees such as faya tree, silk oak (*Grevillea robusta*), and common guava become increasingly tall and abundant with time unless destroyed by wildfire. Improving the grazing regime is unlikely to shift this phase to a more productive grassland phase due to the abundance of invasive plants. Frequent mowing will keep shrub and tree heights in check and, if timed before seedset and combined with lime application, reduce the abundance of Colombian beardgrass and broomsedge. Herbicide treatments are needed to reduce weed abundance. Resprigging of kikuyugrass or reseeding of pangolagrass may be needed, along with removal of livestock until desirable forages have reassumed dominance.

Community 5.1
Common guava - faya tree/sawtooth blackbery - `a`ali`i/broomsedge bluestem - Colombian bluestem

Figure 16. Weedy grassland D Clausnitzer generic photo

Improving the grazing regime is unlikely to shift this phase to a more productive grassland phase due to the abundance of invasive plants. Frequent mowing will keep shrub and tree heights in check and, if timed before seedset and combined with lime application, reduce the abundance of Colombian beardgrass and broomsedge. Herbicide treatments are needed to reduce weed abundance. Resprigging of kikuyugrass or reseeding of pangolagrass may be needed, along with removal of livestock until desirable forages have reassumed dominance.

Forest overstory. A few silk oak (Grevillea robusta) trees of 13 to 30 foot height may be present.

Forest understory. Broomsedge bluestem (Andropogon virginicus), and beardgrass or Colombian bluestem (Schizachyrium condensatum) are the most abundant grasses; yellow foxtail (Setaria parviflora) and smut grass (Sporobolus indicus) are also abundant. Desirable forages such as kikuyugrass and velvetgrass (Holcus lanatus) are present in small amounts. Thickets of sawtooth blackberry (Rubus argutus) are abundant. Native aalii and pukiawe shrubs together comprise about 5% canopy cover. Common guava (Psidium guajava), small silk oak, and faya trees are present and capable of growing and reproducing rapidly.

Table 16. Soil surface cover

Tree basal cover	0.5-1.0%
Shrub/vine/liana basal cover	2-3%
Grass/grasslike basal cover	55-65%
Forb basal cover	0.1-0.5%
Non-vascular plants	0%
Biological crusts	0%
Litter	30-40%
Surface fragments >0.25" and <=3"	0%
Surface fragments >3"	0%
Bedrock	0%
Water	0%
Bare ground	5-10%

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)	0-0%
Downed wood, coarse-large (>9.00" diameter; 10,000-hour fuels)	0-0%

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 18. Canopy structure (% cover)

Height Above Ground (Ft)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.5	0%	0%	0%	1-2%
>0.5 <= 1	0%	0%	5-10%	2-3%
>1 <= 2	1-1%	3-5%	5-10%	2-3%
>2 <= 4.5	3-5%	25-40%	35-40%	1-1%
>4.5 <= 13	1-2%	–	–	–
>13 <= 40	1-2%	–	–	–
>40 <= 80	–	–	–	–
>80 <= 120	–	–	–	–
>120	–	–	–	–

State 6
Invaded Overstory and Understory State

This state is comprised of one plant community dominated by introduced species in both the overstory and understory. Understory vegetation usually is very sparse to nonexistent. Remnant individuals of a few native species may persist. This state might be considered a dead end as far as further succession or transition to another state. Restoration to a facsimile of the Reference State could probably be done by intensive removal of invasive plant species followed by long term weed management and reintroduction of native plant species.

Community 6.1
Faya tree/sawtooth blackbery/weeping grass

Figure 17. Site dominated by faya trees D Clausnitzer generic photo

It is possible that shifts will eventually occur in the composition of introduced species that present, particularly if tall stature, competitive tree species such as silk oak are present. This would not represent a transition to another state. Sites that are completely dominated by dense stands of faya tree typically show no indications (death or partial

death of stands; abundant growth of taller tree species) of yielding to change in the foreseeable future.

Forest overstory. Faya tree generally will become dominant, creating a dense canopy that appears to suppress other species. Taller statured silkoak could potentially come to dominate a site if it invades an open site before faya tree.

A few remnant ohia lehua, koa, or wingleaf soapberry trees may remain as emergents above the canopy of introduced species, but seedlings or saplings are unlikely to be present.

Forest understory. The introduced tree overstory species are highly competitive and produce dense shade. Introduced understory species is often present but not very abundant. Understory species are most abundant on small areas with very shallow soils over pahoehoe. The most abundant understory species typically are weeping grass (Microlaena stipoides) and sawtooth blackberry.

Table 19. Soil surface cover

Tree basal cover	3-4%
Shrub/vine/liana basal cover	0.0-0.1%
Grass/grasslike basal cover	1-2%
Forb basal cover	0%
Non-vascular plants	0.5-1.0%
Biological crusts	0%
Litter	80-90%
Surface fragments >0.25" and <=3"	0%
Surface fragments >3"	0%
Bedrock	0%
Water	0%
Bare ground	0.1-1.0%

Table 20. 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)	0-0%
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***)	1-2 per acre
Tree snag count** (hard***)	1-2 per acre

*** 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 21. Canopy structure (% cover)

Height Above Ground (Ft)	Tree	Shrub/Vine	Grass/ Grasslike	Forb
<0.5	0%	0%	3-5%	0%
>0.5 <= 1	0%	0%	5-10%	1-2%
>1 <= 2	0-1%	1-2%	3-5%	3-5%
>2 <= 4.5	1-1%	5-10%	1-2%	–
>4.5 <= 13	1-1%	–	–	–
>13 <= 40	60-80%	–	–	–
>40 <= 80	0-1%	–	–	–
>80 <= 120	–	–	–	–
>120	–	–	–	–

Transition T1A
State 1 to 2

State 1, Reference State, can transition to State 2, Naturalized Grassland with >25% Large Native Tree Cover, by clearing the forest with heavy machinery or by gradual clearing by allowing cattle access to the forest. Cattle eventually eat or destroy understory ferns, forbs, shrubs, and saplings, opening up the forest so that introduced forage grasses will thrive. Grasslands that were cleared by machinery may have broad cleared areas and isolated islands of trees that later grew in the shelter of slash piles. Cleared areas are planted with desired forage grass species.

Transition T1B
State 1 to 3

State 1, Reference State, can transition to State 2, Naturalized Grassland with <25% Large Native Tree Cover, by clearing the forest with heavy machinery and burning the slash. Cleared areas are planted with desired forage grass species.

Restoration pathway R2A
State 2 to 1

It is possible to restore a Reference State forest, as has been done in Hawaii Volcanoes National Park. Feral and domestic ungulates must be excluded by fences and remaining feral ungulates removed from the restoration site. Well managed domestic ungulates are useful to manage vegetation outside the restoration site or in areas awaiting restoration practices. Long term weed control must be applied to introduced pasture species and the many opportunistic plant species that invade the site after ungulates are removed. Extensive planting of native species would follow. Increased shade from trees growing on the site causes a shift from C4 (warm season) grass dominance (typically kikuyugrass) to shade tolerant C3 (cool season) grasses (primarily meadow ricegrass). This meadow ricegrass layer can be dense and detrimental to establishment of native plants. Attempts have been made to suppress meadow ricegrass by planting native shrubs and tree ferns that create dense shade and produce litter that covers the grass. Some spontaneous regeneration of native plants may occur from the existing seed bank in the soil and seeds from overstory trees.

Transition T2A
State 2 to 3

The mature native trees in State 2 may be destroyed by fire carried by underutilized forage or by weedy grasses such as broomsedge bluestem and Colombian beardgrass. Browsing and trampling by ungulates precludes most native tree reproduction, leading to gradually reduction in tree cover. These processes will cause a transition to State 3, Naturalized Grassland with <25% Native Tree Cover.

Transition T2B

State 2 to 4

Long term continuous grazing or abandonment leads to gradual invasion of State 2 by dense stands of introduced vines, grasses, and forbs as well as weedy trees such as common guava and strawberry guava, causing a transition to State 4, Invaded Understory.

Restoration pathway R3A
State 3 to 1

It is possible to restore a Reference State forest, as has been done in Hawaii Volcanoes National Park. Feral and domestic ungulates must be excluded by fences and remaining feral ungulates removed from the restoration site. Well managed domestic ungulates are useful to manage vegetation outside the restoration site or in areas awaiting restoration practices. Long term weed control must be applied to introduced forage species and the many opportunistic plant species that invade the site after ungulates are removed. Extensive planting of native species would follow. Increased shade from trees growing on the site causes a shift from C4 (warm season) grass dominance (typically kikuyugrass) to shade tolerant C3 (cool season) grasses (primarily meadow ricegrass). This meadow ricegrass layer can be dense and detrimental to establishment of native plants. Attempts have been made to suppress meadow ricegrass by planting native shrubs and tree ferns that create dense shade and produce litter that covers the grass. Some spontaneous regeneration of native plants may occur from the existing seed bank in the soil and seeds from overstory trees, if any are present.

Transition T3A
State 3 to 5

Abandonment of grassland without accompanying weed control results in invasion of the site by blackberries, weedy grasses, and weedy forbs that had previously been suppressed by managed grazing, browsing, and trampling by animals. Alternatively, long term continuous grazing makes grassland susceptible to heavy invasion by introduced weed species. The result if a transition to State 5, Invaded Naturalized Grassland.

Restoration pathway R4A
State 4 to 2

State 4 Invaded Understory State may be converted to State 2 Naturalized Grassland with >25% Native Trees by mechanical clearing or herbicide treatment of understory plants. Native overstory trees may be harvested for timber, destroyed, left to provide shade, or protected if the intention is eventual restoration to State 1 Reference State. If leaving large native trees in place, care must be taken to not damage near-surface roots within about 20 feet of the trees. Introduced forage grasses may then be seeded or sprigged into the site. Herbicide applications will be necessary before and during forage establishment to control emerging weed species.

Transition T4A
State 4 to 6

The large native trees that form the overstory of State 4 Invaded Understory are unable to successfully regenerate due to the competitive understory of introduced species. Eventually the large native trees die and are replaced by introduced tree species.

Restoration pathway R5A
State 5 to 3

Invaded Naturalized Grassland can be restored to State 3 Naturalized Grassland with <25% Large Native Tree Cover by removal of heavy shrub and sapling growth by brush control, herbicidal control of present and reemerging nonwoody invasive species followed by temporary removal of livestock, planting desirable forage species, and later adoption of prescribed grazing practices to maintain the restored grassland in the desired condition.

Transition T5A
State 5 to 6

Invaded Naturalized Grassland transitions to State 6 Invaded Overstory and Understory in the absence of fire, with

abandonment, or in the absence of measures to prevent the growth of a dense canopy of introduced tree species that shades out most understory vegetation.

Restoration pathway R6A
State 6 to 5

The Invaded Overstory and Understory State may be restored to State 5 Invaded Naturalized Grassland State by mechanical clearing or wildfire.

Additional community tables

Table 22. Community 1.1 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (Ft)	Canopy Cover (%)	Diameter (In)	Basal Area (Square Ft/Acre)
Tree							
wingleaf soapberry	SASA4	*Sapindus saponaria*	Native	40–80	45–55	12–32	–
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	40–80	5–15	20–45	–
koa	ACKO	*Acacia koa*	Native	40–80	5–10	24–63	–
kopiko 'ula	PSHA3	*Psychotria hawaiiensis*	Native	13–30	2–5	–	–
naio	MYSA	*Myoporum sandwicense*	Native	13–40	1–2	–	–
Australasian catchbirdtree	PIBR3	*Pisonia brunoniana*	Native	13–40	1–2	–	–
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	13–40	1–2	–	–
kolea lau nui	MYLE2	*Myrsine lessertiana*	Native	13–40	0.5–1	–	–
Australasian catchbirdtree	PIBR3	*Pisonia brunoniana*	Native	13–40	0.5–1	–	–
Hawai'i olive	NESA2	*Nestegis sandwicensis*	Native	13–40	0.5–1	–	–
wingleaf soapberry	SASA4	*Sapindus saponaria*	Native	20–40	0.5–1	–	–
woodland mirrorplant	CORH	*Coprosma rhynchocarpa*	Native	13–25	0.5–1	–	–
Kona cheesewood	PIHO	*Pittosporum hosmeri*	Native	13–40	0.5–1	–	–
melicope	MELIC3	*Melicope*	Native	13–25	0.1–1	–	–
koa	ACKO	*Acacia koa*	Native	13–40	0–0.1	–	–
broadleaf papala	CHOB2	*Charpentiera obovata*	Native	13–25	0–0.1	–	–

Table 23. Community 1.1 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (Ft)	Canopy Cover (%)
Forb/Herb					
peperomia	PEPER	*Peperomia*	Native	0.5–1	0.5–1
Fern/fern ally					
alpine woodfern	DRWA	*Dryopteris wallichiana*	Native	1–2	5–10
palapalai	MIST4	*Microlepia strigosa*	Native	2–3	1–2
Hawai'i air fern	PNSA	*Pneumatopteris sandwicensis*	Native	2–3	0.1–1
Cretan brake	PTCR2	*Pteris cretica*	Native	0.5–1	0.1–1
Boston swordfern	NEEX	*Nephrolepis exaltata*	Native	1–2	0.1–1
Pacific woodfern	DRSA	*Dryopteris sandwicensis*	Native	2–3	0.5–1
spleenwort	ASPLE	*Asplenium*	Native	1–2	0.5–1
royal tonguefern	ELCR2	*Elaphoglossum crassifolium*	Native	0.5–1	0.1–1
weeping fern	LETH6	*Lepisorus thunbergianus*	Native	0.5–1	0.1–1
Shrub/Subshrub					
Waimea pipturus	PIAL2	*Pipturus albidus*	Native	2–13	1–2
Maui mirrorplant	COOC3	*Coprosma ochracea*	Native	2–13	1–2
Florida hopbush	DOVI	*Dodonaea viscosa*	Native	4–13	0–0.1
Tree					
kopiko 'ula	PSHA3	*Psychotria hawaiiensis*	Native	2–13	1–2
kolea lau nui	MYLE2	*Myrsine lessertiana*	Native	2–13	0–1
melicope	MELIC3	*Melicope*	Native	2–13	0–1
Hawai'i olive	NESA2	*Nestegis sandwicensis*	Native	2–13	0–1
mamani	SOCH	*Sophora chrysophylla*	Native	5–13	0.1–1
woodland mirrorplant	CORH	*Coprosma rhynchocarpa*	Native	2–13	0.5–1
wingleaf soapberry	SASA4	*Sapindus saponaria*	Native	2–13	0.5–1
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	2–13	0–0.1
koa	ACKO	*Acacia koa*	Native	2–13	0–0.1
naio	MYSA	*Myoporum sandwicense*	Native	2–13	0–0.1
Australasian catchbirdtree	PIBR3	*Pisonia brunoniana*	Native	2–13	0–0.1
aiea	NOTHO3	*Nothocestrum*	Native	2–13	0–0.1
Kilauea hau kuahiwi	HIGI	*Hibiscadelphus giffardianus*	Native	2–13	0–0.1
broadleaf papala	CHOB2	*Charpentiera obovata*	Native	4–13	0–0.1
Kona cheesewood	PIHO	*Pittosporum hosmeri*	Native	2–13	0–0.1
Hawai'i yellowwood	OCKI	*Ochrosia kilaueaensis*	Native	2–13	0–0.1
pricklyash	ZANTH	*Zanthoxylum*	Native	2–13	0–0.1
Tree Fern					
hapu'u	CIGL	*Cibotium glaucum*	Native	2–13	0.5–1
Vine/Liana					
oceanblue morning-glory	IPIN	*Ipomoea indica*	Native	2–4	2–5
lava bur cucumber	SIAN4	*Sicyos anunu*	Native	2–10	0.5–1
Maile	ALST11	*Alyxia stellata*	Native	2–15	0.5–1

Table 24. Community 2.1 plant community composition

Group	Common Name	Symbol	Scientific Name	Annual Production (Lb/Acre)	Foliar Cover (%)
Grass/Grasslike					
1	**Naturalized Grasses**			3930–4950	
	kikuyugrass	PECL2	*Pennisetum clandestinum*	2310–3300	–
	digitgrass	DIER	*Digitaria eriantha*	1320–1650	–
	dallisgrass	PADI3	*Paspalum dilatatum*	330–660	–
	weeping grass	MIST	*Microlaena stipoides*	330–528	–
	orchardgrass	DAGL	*Dactylis glomerata*	66–330	–
	common velvetgrass	HOLA	*Holcus lanatus*	66–330	–
	sweet vernalgrass	ANOD	*Anthoxanthum odoratum*	66–200	–
	Oahu flatsedge	CYHY2	*Cyperus hypochlorus*	0–66	–
Forb					
2	**Forbs and Ferns**			200–330	
	garden vetch	VISA	*Vicia sativa*	132–264	–
	climbing dayflower	CODI5	*Commelina diffusa*	66–200	–
	alpine woodfern	DRWA	*Dryopteris wallichiana*	0–66	–
	narrowleaf plantain	PLLA	*Plantago lanceolata*	0–66	–
	western brackenfern	PTAQ	*Pteridium aquilinum*	0–66	–
	Cretan brake	PTCR2	*Pteris cretica*	0	–
	Carolina geranium	GECA5	*Geranium carolinianum*	0	–
	bull thistle	CIVU	*Cirsium vulgare*	0	–
Tree					
3	**Trees and Shrubs**			790–1190	
	arctic pearlwort	SASA	*Sagina saginoides*	32–95	–
	mamani	SOCH	*Sophora chrysophylla*	0–66	–
	naio	MYSA	*Myoporum sandwicense*	0–66	–
	guava	PSGU	*Psidium guajava*	0–66	–
	sawtooth blackberry	RUAR2	*Rubus argutus*	0–66	–
	koa	ACKO	*Acacia koa*	24–60	–
	'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	24–60	–
	Jerusalem cherry	SOPS	*Solanum pseudocapsicum*	0	–
	American black nightshade	SOAM	*Solanum americanum*	0	–

Table 25. Community 2.2 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (Ft)	Canopy Cover (%)	Diameter (In)	Basal Area (Square Ft/Acre)
Tree							
wingleaf soapberry	SASA4	*Sapindus saponaria*	Native	40–80	5–40	12–32	–
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	40–80	5–30	30–45	–
koa	ACKO	*Acacia koa*	Native	40–80	5–10	15–63	–
naio	MYSA	*Myoporum sandwicense*	Native	13–30	1–2	–	–
kolea lau nui	MYLE2	*Myrsine lessertiana*	Native	13–25	1–2	–	–

Table 26. Community 2.2 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (Ft)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
weeping grass	MIST	*Microlaena stipoides*	Introduced	1–2	5–40
kikuyugrass	PECL2	*Pennisetum clandestinum*	Introduced	0.5–1.5	15–30
broomsedge bluestem	ANVI2	*Andropogon virginicus*	Introduced	2–3	5–10
Colombian bluestem	SCCO10	*Schizachyrium condensatum*	Introduced	2–3	5–10
common velvetgrass	HOLA	*Holcus lanatus*	Introduced	1–2	3–5
smut grass	SPIN4	*Sporobolus indicus*	Introduced	0.5–1	3–5
sweet vernalgrass	ANOD	*Anthoxanthum odoratum*	Introduced	1–2	3–5
crabgrass	DIGIT2	*Digitaria*	Introduced	2–3	1–2
Forb/Herb					
narrowleaf plantain	PLLA	*Plantago lanceolata*	Introduced	0.1–0.5	3–5
climbing dayflower	CODI5	*Commelina diffusa*	Introduced	0.5–1	1–2
Carolina geranium	GECA5	*Geranium carolinianum*	Introduced	0.1–0.5	1–2
garden vetch	VISA	*Vicia sativa*	Introduced	0.5–1	0.1–1
American black nightshade	SOAM	*Solanum americanum*	Introduced	2–3	0.5–1
Jerusalem cherry	SOPS	*Solanum pseudocapsicum*	Introduced	2–3	0.1–1
bull thistle	CIVU	*Cirsium vulgare*	Introduced	2–3	0–0.1
Fern/fern ally					
western brackenfern	PTAQ	*Pteridium aquilinum*	Native	2–3	0.1–1
Cretan brake	PTCR2	*Pteris cretica*	Native	0.5–1	0–0.1
Tree					
guava	PSGU	*Psidium guajava*	Introduced	2–5	3–5
Tree Fern					
hapu'u	CIGL	*Cibotium glaucum*	Native	6–10	0–0.1
Vine/Liana					
sawtooth blackberry	RUAR2	*Rubus argutus*	Introduced	2–4	1–2

Table 27. Community 3.1 plant community composition

Group	Common Name	Symbol	Scientific Name	Annual Production (Lb/Acre)	Foliar Cover (%)
Grass/Grasslike					
1	**Naturalized Grasses**			2800–3200	
	kikuyugrass	PECL2	*Pennisetum clandestinum*	1260–1920	–
	dallisgrass	PADI3	*Paspalum dilatatum*	140–320	–
	digitgrass	DIER	*Digitaria eriantha*	140–320	–
	smut grass	SPIN4	*Sporobolus indicus*	28–160	–
	Colombian bluestem	SCCO10	*Schizachyrium condensatum*	28–64	–
	broomsedge bluestem	ANVI2	*Andropogon virginicus*	28–64	–
	sweet vernalgrass	ANOD	*Anthoxanthum odoratum*	1–6	–
	orchardgrass	DAGL	*Dactylis glomerata*	1–6	–
	common velvetgrass	HOLA	*Holcus lanatus*	1–6	–
	perennial ryegrass	LOPE	*Lolium perenne*	0–2	–
	weeping grass	MIST	*Microlaena stipoides*	0–2	–
	Oahu flatsedge	CYHY2	*Cyperus hypochlorus*	0–2	–
	Kentucky bluegrass	POPR	*Poa pratensis*	0–2	–
Forb					
2	**Naturalized Forbs**			320–480	
	garden vetch	VISA	*Vicia sativa*	3–14	–
	climbing dayflower	CODI5	*Commelina diffusa*	3–10	–
	narrowleaf plantain	PLLA	*Plantago lanceolata*	0–5	–
	Carolina geranium	GECA5	*Geranium carolinianum*	0	–
	tropical whiteweed	AGCO	*Ageratum conyzoides*	0	–
	bull thistle	CIVU	*Cirsium vulgare*	0	–
Shrub/Vine					
3	**Naturalized Shrubs and Small Trees**			0–120	
	Peruvian groundcherry	PHPE4	*Physalis peruviana*	0–1	–
	guava	PSGU	*Psidium guajava*	0–1	–
	sawtooth blackberry	RUAR2	*Rubus argutus*	0–1	–
	American black nightshade	SOAM	*Solanum americanum*	0	–
	Jerusalem cherry	SOPS	*Solanum pseudocapsicum*	0	–

Table 28. Community 3.2 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (Ft)	Canopy Cover (%)	Diameter (In)	Basal Area (Square Ft/Acre)
Tree							
wingleaf soapberry	SASA4	*Sapindus saponaria*	Native	40–80	0–25	–	–
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	40–80	0–25	–	–
koa	ACKO	*Acacia koa*	Native	40–80	0–10	–	–

Table 29. Community 3.2 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (Ft)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
Colombian bluestem	SCCO10	*Schizachyrium condensatum*	Introduced	2–3	25–35
broomsedge bluestem	ANVI2	*Andropogon virginicus*	Introduced	2–3	25–35
kikuyugrass	PECL2	*Pennisetum clandestinum*	Introduced	0.5–1.5	10–25
weeping grass	MIST	*Microlaena stipoides*	Introduced	0.5–1	1–15
sweet vernalgrass	ANOD	*Anthoxanthum odoratum*	Introduced	1–2	3–5
common velvetgrass	HOLA	*Holcus lanatus*	Introduced	1–2	3–5
smut grass	SPIN4	*Sporobolus indicus*	Introduced	0.5–1	3–5
crabgrass	DIGIT2	*Digitaria*	Introduced	2–3	1–2
Forb/Herb					
narrowleaf plantain	PLLA	*Plantago lanceolata*	Introduced	0.2–0.5	3–5
Jerusalem cherry	SOPS	*Solanum pseudocapsicum*	Introduced	2–3	0.1–1
climbing dayflower	CODI5	*Commelina diffusa*	Introduced	0.5–1	0.5–1
garden vetch	VISA	*Vicia sativa*	Introduced	0.2–0.5	0.1–1
Carolina geranium	GECA5	*Geranium carolinianum*	Introduced	0.3–0.5	0.5–1
American black nightshade	SOAM	*Solanum americanum*	Introduced	2–3	0.1–1
bull thistle	CIVU	*Cirsium vulgare*	Introduced	2–3	0–0.1
Tree					
guava	PSGU	*Psidium guajava*	Introduced	2–5	3–5
Vine/Liana					
sawtooth blackberry	RUAR2	*Rubus argutus*	Introduced	2–4	1–2

Table 30. Community 4.1 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (Ft)	Canopy Cover (%)	Diameter (In)	Basal Area (Square Ft/Acre)
Tree							
wingleaf soapberry	SASA4	*Sapindus saponaria*	Native	40–80	25–40	–	–
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	40–80	5–10	–	–
koa	ACKO	*Acacia koa*	Native	40–80	1–2	–	–
naio	MYSA	*Myoporum sandwicense*	Native	13–25	0–0.1	–	–
mamani	SOCH	*Sophora chrysophylla*	Native	13–25	0–0.1	–	–
Australasian catchbirdtree	PIBR3	*Pisonia brunoniana*	Native	13–25	0–0.1	–	–
kolea lau nui	MYLE2	*Myrsine lessertiana*	Native	13–25	0–0.1	–	–

Table 31. Community 4.1 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (Ft)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
weeping grass	MIST	*Microlaena stipoides*	Introduced	0.5–1	3–5
common velvetgrass	HOLA	*Holcus lanatus*	Introduced	1–2	1–2
broomsedge bluestem	ANVI2	*Andropogon virginicus*	Introduced	2–3	1–2
Colombian bluestem	SCCO10	*Schizachyrium condensatum*	Introduced	1–2	1–2
kikuyugrass	PECL2	*Pennisetum clandestinum*	Introduced	2–3	1–2
basketgrass	OPHI	*Oplismenus hirtellus*	Introduced	0.5–1	1–2
Forb/Herb					
spreading snakeroot	AGRI2	*Ageratina riparia*	Introduced	1–2	0.5–1
Jerusalem cherry	SOPS	*Solanum pseudocapsicum*	Introduced	2–3	0.1–1
climbing dayflower	CODI5	*Commelina diffusa*	Introduced	0.5–1	0.5–1
pukamole	LYMA3	*Lythrum maritimum*	Native	1–2	0–0.1
Fern/fern ally					
western brackenfern	PTAQ	*Pteridium aquilinum*	Native	1–2	3–5
scaly swordfern	NEHI	*Nephrolepis hirsutula*	Introduced	1–2	3–5
Cretan brake	PTCR2	*Pteris cretica*	Native	0.5–1	0.5–1
alpine woodfern	DRWA	*Dryopteris wallichiana*	Native	1–2	0–0.1
weeping fern	LETH6	*Lepisorus thunbergianus*	Native	0.5–1	0–0.1
Shrub/Subshrub					
lantana	LACA2	*Lantana camara*	Introduced	2–4	1–2
Florida hopbush	DOVI	*Dodonaea viscosa*	Native	3–6	0–0.1
Tree					
strawberry guava	PSCA	*Psidium cattleianum*	Introduced	2–5	0.1–1
guava	PSGU	*Psidium guajava*	Introduced	2–4	0–0.1
Vine/Liana					
sawtooth blackberry	RUAR2	*Rubus argutus*	Introduced	2–5	5–65
oceanblue morning-glory	IPIN	*Ipomoea indica*	Native	2–5	3–5

Table 32. Community 5.1 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (Ft)	Canopy Cover (%)	Diameter (In)	Basal Area (Square Ft/Acre)
Tree							
silkoak	GRRO	*Grevillea robusta*	Introduced	13–30	0.5–1	–	–

Table 33. Community 5.1 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (Ft)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
broomsedge bluestem	ANVI2	*Andropogon virginicus*	Introduced	–	20–25
Colombian bluestem	SCCO10	*Schizachyrium condensatum*	Introduced	2–3	20–25
kikuyugrass	PECL2	*Pennisetum clandestinum*	Introduced	0.5–1	3–5
smut grass	SPIN4	*Sporobolus indicus*	Introduced	1–2	3–5
marsh bristlegrass	SEPA10	*Setaria parviflora*	Introduced	1–2	3–5
crabgrass	DIGIT2	*Digitaria*	Introduced	2–3	1–2
sweet vernalgrass	ANOD	*Anthoxanthum odoratum*	Introduced	1–2	1–2
common velvetgrass	HOLA	*Holcus lanatus*	Introduced	1–2	1–2
Forb/Herb					
Carolina geranium	GECA5	*Geranium carolinianum*	Introduced	0.5–1	0.5–1
American black nightshade	SOAM	*Solanum americanum*	Introduced	2–3	0.5–1
Jerusalem cherry	SOPS	*Solanum pseudocapsicum*	Introduced	2–3	0.5–1
narrowleaf plantain	PLLA	*Plantago lanceolata*	Introduced	0.5–1	0.5–1
bull thistle	CIVU	*Cirsium vulgare*	Introduced	2–3	0–0.1
Shrub/Subshrub					
Florida hopbush	DOVI	*Dodonaea viscosa*	Native	2–4	3–5
pukiawe	STTA	*Styphelia tameiameiae*	Native	2–5	1–2
firetree	MOFA	*Morella faya*	Introduced	2–15	1–2
Tree					
guava	PSGU	*Psidium guajava*	Introduced	2–4	3–5
Vine/Liana					
sawtooth blackberry	RUAR2	*Rubus argutus*	Introduced	2–5	35–40

Table 34. Community 6.1 forest overstory composition

Common Name	Symbol	Scientific Name	Nativity	Height (Ft)	Canopy Cover (%)	Diameter (In)	Basal Area (Square Ft/Acre)
Tree							
firetree	MOFA	*Morella faya*	Introduced	13–25	65–80	–	–
silkoak	GRRO	*Grevillea robusta*	Introduced	20–60	0.1–1	–	–
'ohi'a lehua	MEPO5	*Metrosideros polymorpha*	Native	40–80	0–0.1	–	–
wingleaf soapberry	SASA4	*Sapindus saponaria*	Native	40–80	0–0.1	–	–
koa	ACKO	*Acacia koa*	Native	40–80	0–0.1	–	–

Table 35. Community 6.1 forest understory composition

Common Name	Symbol	Scientific Name	Nativity	Height (Ft)	Canopy Cover (%)
Grass/grass-like (Graminoids)					
weeping grass	MIST	*Microlaena stipoides*	Introduced	1–2	5–10
Colombian bluestem	SCCO10	*Schizachyrium condensatum*	Introduced	2–3	3–5
kikuyugrass	PECL2	*Pennisetum clandestinum*	Introduced	0.5–1.5	3–5
broomsedge bluestem	ANVI2	*Andropogon virginicus*	Introduced	2–3	1–5
crabgrass	DIGIT2	*Digitaria*	Introduced	1–2	0–1
Fern/fern ally					
western brackenfern	PTAQ	*Pteridium aquilinum*	Native	1–2	3–5
Tree					
strawberry guava	PSCA	*Psidium cattleianum*	Introduced	2–5	1–2
firetree	MOFA	*Morella faya*	Native	2–13	0.5–1
Vine/Liana					
sawtooth blackberry	RUAR2	*Rubus argutus*	Introduced	2–5	5–15

Animal community

Native Wildlife
This ecological site provides habitat to the following native birds: elepaio (Chasiempis sandwichensis), amakihi (Hemignathus virens), apapane (Himatione sanguinea), iiwi (Vestiaria coccinea), and omao (Myadestes obscurus). It also is home to the Hawaiian hoary bat or opeapea (Lasiurus cenarius semotus). These species may be encountered within all community phases but are most prevalent in open canopy native forest and forest adjacent to clearings. Community phases that provide open grassland or savanna-like settings 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), black francolin (Francolinus francolinus), and kalij pheasant (Lophura leucomelanos) are considered to be game birds.

Feral pigs and sheep are common, while feral cattle can potentially be present. 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 phases 2.1 and 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) 0.40-0.59 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 phases 2.1 and 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.

These community phases are 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 plant community is to be maintained. Herbaceous forage can be deficient in protein during the drier months.

Hydrological functions

Water infiltration and retention tend to be high on these deep to very deep volcanic ash soils. The deep canopy and heavy litter layer of the Reference State keep soil erosion to a minimum.

The tall, dense grass growth in well-managed grasslands provides considerable protection against erosion.

Recreational uses

Hiking, hunting, and bird watching are possible recreational uses in this ecological site. Good examples of the Reference Community can be accessed by vehicles and foot trails in the National Park.

Wood products

There is excellent potential for production of timber in this ecological site, including eucalyptus and high-value specialty woods such as koa.

Very little site index information is not available for Hawaiian forests, as tropical trees do not form annual tree rings from which tree age can be estimated. Long-term measurements have been made of some tree plantations, primarily on introduced timber species and on a limited number of soils.

In Reference State native forests, estimates of standing timber ranged from 2000 to 6000 cubic feet per acre for wingleaf soapberry and about 1000 cubic feet per acre each for ohia lehua and koa.

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° 26′ 23″
Longitude	155° 18′ 11″
General legal description	In Hawaii Volcanoes National Park. From Hwy. 11, go mauka on Mauna Loa Trail about 1.5 miles to Bird Park traffic circle and park vehicle. Walk NW along trail 0.15 mile into Kipuka Puaulu; walk into forest to NW 75 yards.

Other references

Armstrong RW. 1973. Atlas of Hawaii. University of Hawaii Press, Honolulu.

Athens JS. Ch. 12 Hawaiian Native Lowland Vegetation in Prehistory in Historical Ecology in the Pacific Islands – Prehistoric Environmental and Landscape Change. Kirch PV and TL Hunt, eds. 1997. Yale U. Press, New Haven.

Burney, DA, HF James, LP Burney, SL Olson, W Kikuchi, WL Wagner, M Burney, D McCloskey, D Kikuchi, FV Grady, R Gage II, and R Nishek. 2001. Fossil evidence for a diverse biota from Kauai and its transformation since human arrival. Ecological Monographs 71:615-641.

Clark JT. 1983. Report 3: The Waimea-Kawaihae Region: Historical Background. In Archaeological investigations of the Mudlane-Waimea-Kawaihae Road Corridor, Island of Hawaii: an Interdisciplinary Study of an Environmental Transect. Clark JT and Kirch PV, eds. Dept. of Anthropology, Bernice Pauahi Bishop Museum, Report 83-1, Honolulu, HI.

Craighill ES and EG Handy. 1991. Native Planters in Old Hawaii – Their Life, Lore, and Environment. Bernice P. Bishop Museum Bulletin 233, Bishop Museum Press, Honolulu, HI

Cuddihy LW and CP Stone. 1990. Alteration of Native Hawaiian Vegetation: Effects of Humans, Their Activities and Introductions. Honolulu: University of Hawaii Cooperative National Park Resources Study Unit.

Hazlett RW and DW Hyndman. 1996. Roadside Geology of Hawaii. Mountain Press Publishing Company, Missoula MT.

Henke LA. 1929. A Survey of Livestock in Hawaii. Research Publication No. 5. University of Hawaii, Honolulu.

Jacobi JD. 1989. Vegetation Maps of the Upland Plant Communities on the Islands of Hawaii, Maui, Molokai, and Lanai. Technical Report 68. Cooperative National Park Resources Studies Unit, University of Hawaii at Manoa and National Park Service.

Kirch PV. 1982. The impact of the prehistoric Polynesians in the Hawaiian ecosystem. Pacific Science 36(1):1-14.

Kirch PV. 1985. Feathered Gods and Fishhooks: An Introduction to Hawaiian Archaeology and Prehistory. Honolulu: University of Hawaii Press.

Kirch PV. 2000. On the Road of the Winds: An Archaeological History of the Pacific Islands Before European Contact. Berkeley: University of California Press.

Little EL Jr. and RG Skolmen. 1989. Common Forest Trees of Hawaii (Native and Introduced). US Department of Agriculture-US Forest Service Agriculture Handbook No. 679. (out of print). Available at www.fs.fed.us/psw/publications/documents/misc/ah679.pdf

Loh RK. 2004. Complete vegetation map of Hawaii Volcanoes National park below 8,000 ft elevation. US National Park Service.

Mueller-Dombois D and FR Fosberg. 1998. Vegetation of the Tropical Pacific Islands. Springer-Verlag New York, Inc.

Palmer DD. 2003. Hawaii's Ferns and Fern Allies. University of Hawaii Press, Honolulu.

Pratt HD. 1998. A Pocket Guide to Hawaii's Trees and Shrubs. Mutual Publishing, Honolulu.

Ripperton JC and EY Hosaka. 1942. Vegetation zones of Hawaii. Hawaii Agricultural Experiment Station Bulletin 89:1-60.

Rock JF. The Indigenous Trees of the Hawaiian Islands. 1st edition 1913, reprinted 1974, Charles E. Tuttle Company, Rutland, VT and Tokyo, Japan.

Shoji SD, M Nanzyo, and R Dahlgren. 1993. Volcanic Ash Soils: Genesis, Properties and Utilization. Elsevier, New York.

Sohmer SH and R Gustafson. 2000. Plants and Flowers of Hawaii. University of Hawaii Press, Honolulu.

Steadman DW. 1995. Prehistoric extinctions of Pacific island birds: biodiversity meets zooarchaeology. Science 267:1123-1131.

USDA-NRCS-PIA T&E Species GIS files. Not publicly available.

USDI-USGS. 2006. A GAP Analysis of Hawaii. Final Report and Data.

Vitousek P. 2004. Nutrient Cycling and Limitation: Hawaii as a Model Ecosystem. Princeton University Press, Princeton and Oxford.

Wagner WL, DR Herbst, and SH Sohmer. 1999. Manual of the Flowering Plants of Hawai`i, Revised Edition. Bishop Museum Press, Honolulu.

Welch DJ 1983. Report 5: Archaeological investigations in Section 2. In Archaeological investigations of the Mudlane-Waimea-Kawaihae Road Corridor, Island of Hawaii: an Interdisciplinary Study of an Environmental Transect. Clark JT and Kirch PV, eds. Dept. of Anthropology, Bernice Pauahi Bishop Museum, Report 83-1, Honolulu, HI.

Whistler WA. 1995. Wayside Plants of the Islands: a Guide to the Lowland Flora of the Pacific Islands. Isle Botanica, Honolulu.

Contributors

David Clausnitzer
Loretta Metz
Joseph May

Acknowledgments

Assistance, advice, review, and/or insights:

Mick Castillo
Michael Constantinides, NRCS-PIA
Susan Cordell, USFS
Gordon Cran, Kapapala Ranch
David Leonard, volunteer
JB Friday, UH Forestry Extension
Rick Gordon
Basil Hansen, The Nature Conservancy
Jennifer Higashino, USFWS and NRCS
Flint Hughes, USFS
Chris Jasper, NRCS Soil Survey
Mel Johansen, The Nature Conservancy
Kathy Kawakami, US Army Pohakuloa Training Ground
Rhonda Loh, Volcanoes National Park
Kamehameha Schools/Bishop Estate
Miles Nakahara, Hawaii DOFAW
Laura Nelson, The Nature Conservancy and NRCS
Patrick Niemeyer, NRCS Soil Survey
Billy Paris, rancher
John Pipan
Jon Price, USGS
John Replogle, The Nature Conservancy
Paul Scowcroft, USFS
Earl Spence, grazing consultant
Jim Thain
Mike Tomich
Quentin Tomich
Tim Tunison, Volcanoes National Park
Jill Wagner, consultant, Future Forests
Rick Warschauer

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:**
