USDA Natural Resources Conservation Service

# Ecological site VX165X01X001
# Isothermic Ustic Naturalized Grassland

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## General information

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

## MLRA notes

Major Land Resource Area (MLRA): 165X–Subhumid Intermediate Mountain Slopes

This MLRA occurs in the State of Hawaii on the islands of Molokai, Oahu, and Kauai. Elevation ranges from 400 to 3,700 feet (120 to 1,130 meters). It is on leeward, drier, intermediate mountain slopes on rolling slopes that are dissected by many steep and very steep gulches. The geology is basic igneous rock (primarily basalt). Interfluves are influenced volcanic ash. Average annual precipitation ranges from 25 to 60 inches (635 to 1,525 millimeters). Most of the rainfall occurs from November through March. Average annual air temperature is 61 to 74 degrees F (16 to 23 degrees C), with little seasonal variation. Dominant soils are Inceptisols, Ultisols, Oxisols, Andisols, and Spodosols with an isothermic, soil temperature regime and ustic or udic soil moisture regimes. Vegetation consists of forest, grassland, and shrubland.

## Classification relationships

This ecological site occurs within Major Land Resource Area (MLRA) 165 - Subhumid Intermediate Mountain Slopes.

## Ecological site concept

This ecological site is largely naturalized grassland at low elevations on leeward Kauai, leeward Molokai, and a small area on the West Maui Mountains. Principal landowners are private land companies, ranches, and the State of Hawaii. It is accessible on Kauai along Route 550 above Waimea, on Molokai along Route 470, and along Route 340 northwest of Kahului.

The central concept of the Isothermic Ustic Naturalized Grassland is of well drained, moderately deep to very deep soils, mostly with humic or umbric (high organic matter but often low base saturation) properties that formed in residuum from basic igneous rock, in some cases with an overlayer of volcanic ash. Annual air temperatures and rainfall are associated with warm (isothermic), seasonally dry (ustic) soil conditions. Elevations range from 500 to 2500 feet (155 to 770 meters); extremes are as low as 200 feet (60 meters) and as high as 3400 feet (1045 meters). Because very little of the original native vegetation remains, the reference state of this ecological site consists of the dominant naturalized grassland vegetation. While the dominant grass species is kikuyugrass (Cenchrus clandestinus (syn. Pennisetum clandestinum)), guineagrass (Urochloa maxima) is abundant at moderate elevations and buffelgrass can occur onthe lowest leeward extremes. Common naturalized trees are christmasberry (*Schinus terebinthifolius*) and haole (*Leucaena leucocephala*). The original native vegetation was dry to transitionally moist forest, which is often referred to as “mesic forest” in botanical literature. Common species, based on the current environment and remnant occurrences, were ohia lehua (*Metrosideros polymorpha*), olopua (*Nestegis sandwicensis*), lama (Diospyros sandwicense), alahee (*Psydrax odorata*), naio (Myoporum sandwicense), koaia (Acacia koaia), aalii (*Dodonaea viscosa*), pukiawe (Leptecophylla (Styphelia) tameiameiae), ulei (*Osteomeles anthyllidifolia*), and huehue (*Cocculus orbiculatus*).

## Associated sites

| | |
|---|---|
| VX158X01X002 | **Isohyperthermic Torric Naturalized Grassland Kiawe/buffelgrass (Prosopis pallida/Pennisetum ciliare)**<br>The Isohyperthermic Torric Naturalized Grassland has a warmer, drier climate, different plant species, and lower annual aboveground production than this ecological site. |
| VX158X01X004 | **Rocky Isohyperthermic Torric Naturalized Grassland Kiawe/uhaloa/buffelgrass (Prosopis pallida/Waltheria indica/Pennisetum ciliare)**<br>The Rocky Isohyperthermic Torric Naturalized Grassland has a warmer, drier climate, lower water holding capacity in the soil, different plant species, and lower annual aboveground production than this ecological site. |
| VX158X01X005 | **Naturalized Grassland 50 to 90 inch PZ Ohia lehua/kikuyugrass (Metrosideros polymorpha/Pennisetum clandestinum)**<br>The Naturalized Grassland 50 to 90 Inch Precipitation Zone has a cooler, moister climate, different plant species, and higher annual aboveground productiion than this ecological site. |
| VX165X01X002 | **Cool Isothermic Udic Forest**<br>The Cool Isothermic Udic Forest occurs with this ecological site on Kauai, but it is at higher, cooler, moister elevations. |

## Similar sites

| | |
|---|---|
| VX161A01X009 | **Isothermic Ustic Naturalized Grassland**<br>Isothermic Naturalized Grassland (R161AY009HI) occurs only on the island of Hawaii. It is more broadly defined than this ecological site, occurring over a wider range of rainfall and elevaions. The two ecological sites overlap in species occurrences and production. |
| VX166X01X002 | **Isothermic Ustic Naturalized Grassland**<br>Isothermic Ustic Naturalized Grassland (R166XY002HI) occurs on Lanai and Molokai. It has generally lower precipitation, shares many plant species, and has lower production than this ecological site. |

**Table 1. Dominant plant species**

| | |
|---|---|
| Tree | (1) *Leucaena leucocephala* |
| Shrub | Not specified |
| Herbaceous | (1) *Pennisetum clandestinum*<br>(2) *Urochloa maxima* |

## Legacy ID

R165XY001HI

## Physiographic features

This ecological site occurs on lava flows on ash fields, interfluves, and mountain slopes of shield volcanoes. Lava flows are aa (loose, cobbly) or pahoehoe (smooth, relatively unbroken).

**Table 2. Representative physiographic features**

| | |
|---|---|
| Landforms | (1) Shield volcano > Ash field<br>(2) Shield volcano > Interfluve<br>(3) Shield volcano > Mountain slope |
| Runoff class | Medium to very high |
| Flooding frequency | None |
| Ponding frequency | None |
| Elevation | 500–2,500 ft |
| Slope | 3–45% |
| Water table depth | 60 in |
| Aspect | W, NE, E, SE, SW |

**Table 3. Representative physiographic features (actual ranges)**

| | |
|---|---|
| Runoff class | Not specified |
| Flooding frequency | Not specified |
| Ponding frequency | Not specified |
| Elevation | 200–3,000 ft |
| Slope | 3–70% |
| Water table depth | Not specified |

## Climatic features

Summary for this ecological site
Average annual precipitation ranges from 30 to 60 inches (750 to 1500 millimeters), with extreme average annual precipitation of 24 to 80 inches (600 to 2000 millimeters). Most rainfall occurs from October through April. Average annual temperature ranges from 67 to 70 degrees F (19 to 21 degrees C).

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

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

Two seasons can be defined during the year: a seven-month winter season from October through April and a five-month summer season from May through September. Summer has warmer temperatures, steadier and stronger trade winds, few widespread rainstorms, and generally lower average monthly rainfall than winter. Differences in rainfall amounts between winter and summer are most marked in low elevation dry areas; wetter areas exhibit less seasonal variation in rainfall.

On the windward sides of the island, cool, moist air at higher elevations descends toward the ocean where it meets the trade winds; this process brings rainfall, often at night, to lower elevation areas.

Extensive low-pressure systems often approach the islands from the west, producing heavy rainstorms that primarily affect the leeward sides, but can envelope the entire island. These major storms occur most frequently between October and March.

Sea-to-land naulu winds regularly flow up the western and southern slopes of Haleakala on Maui, forming clouds on these faces of the mountain between about 3000 to 6000 feet (925 to 1850 meters). These clouds form a shadow at lower elevations and produce fog drip at higher elevations where the clouds contact the mountain (Leopold 1949; Schroeder 1981).

**Table 4. Representative climatic features**

| | |
|---|---|
| Frost-free period (characteristic range) | 365 days |
| Freeze-free period (characteristic range) | 365 days |
| Precipitation total (characteristic range) | 28-53 in |
| Frost-free period (actual range) | 365 days |
| Freeze-free period (actual range) | 365 days |
| Precipitation total (actual range) | 22-60 in |
| Frost-free period (average) | 365 days |
| Freeze-free period (average) | 365 days |
| Precipitation total (average) | 41 in |

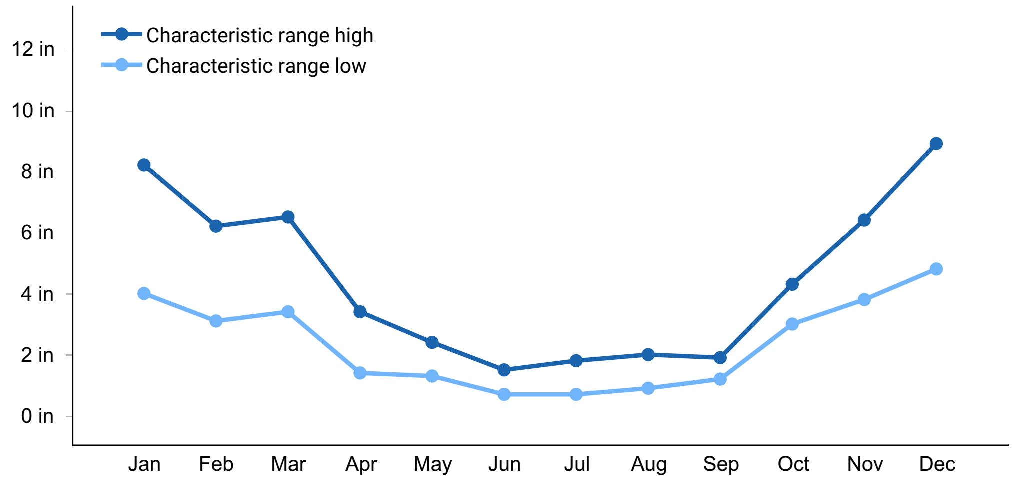


**Figure 1. Monthly precipitation range**

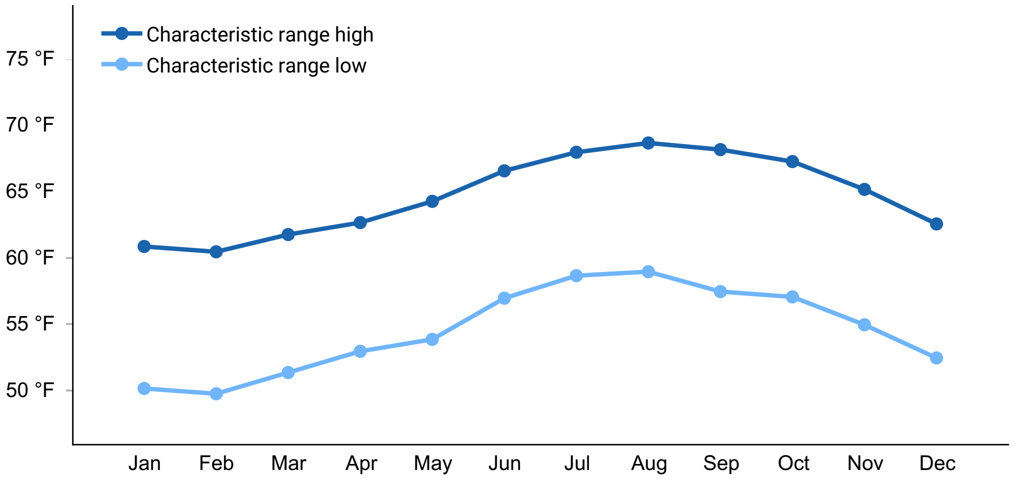


**Figure 2. Monthly minimum temperature range**

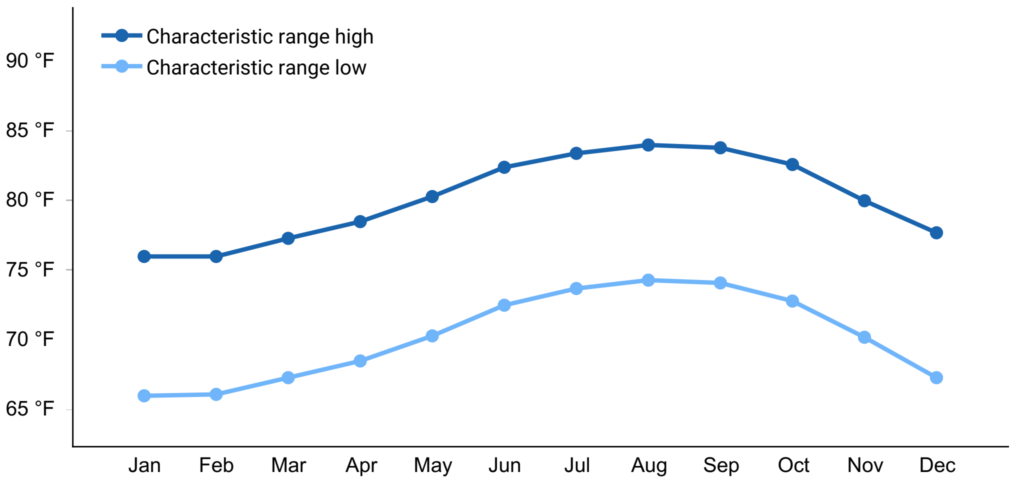


**Figure 3. Monthly maximum temperature range**

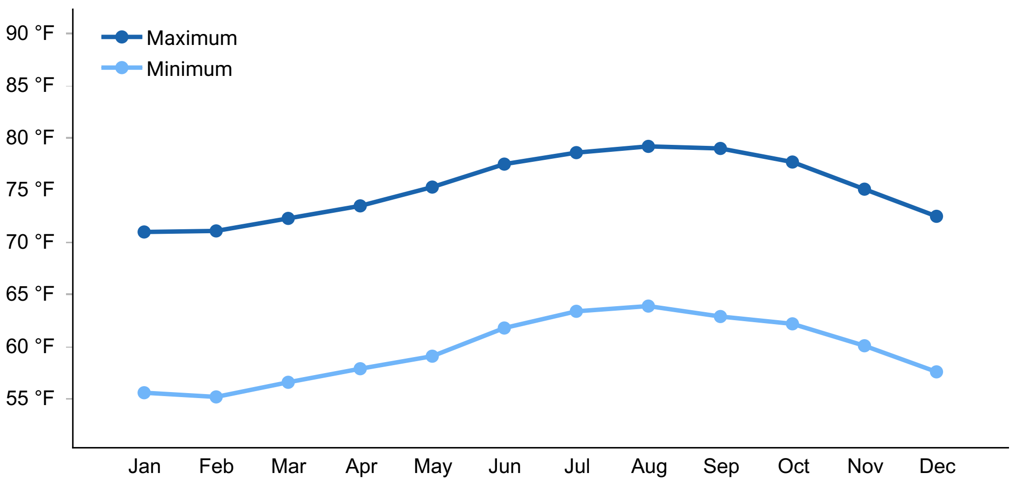


**Figure 4. Monthly average minimum and maximum temperature**

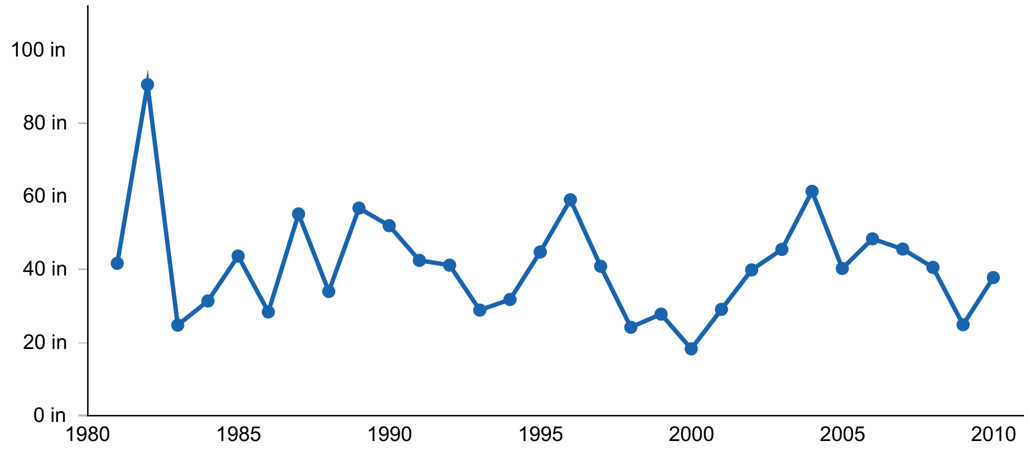


**Figure 5. Annual precipitation pattern**

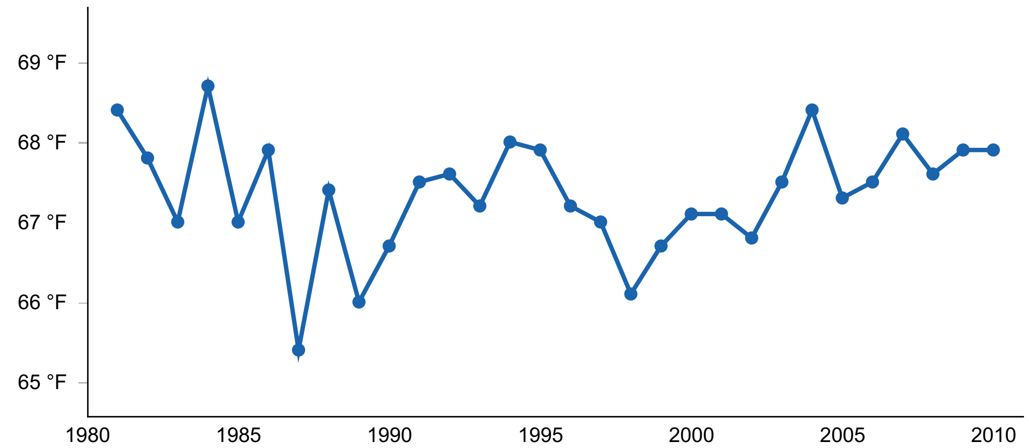


**Figure 6. Annual average temperature pattern**

## Climate stations used

- (1) KANALOHULUHULU 1075 [USC00513099], Hanapepe, HI
- (2) BARKING SANDS [USW00022501], Kekaha, HI

## Influencing water features

While this ecological site is primarily dissected by intermittent streams, it is also dissected by a few perennial streams.

## Soil features

This ecological site is correlated with soils in three soil orders: Ultisols, Oxisols, and Andisols. They are well drained and moderately deep (20 to 40 inches or 50 to 100 centimeters) to very deep (deeper than 60 inches or 150 centimeters). All of the soils formed in place in residuum of basic igneous rock; two soil series also had volcanic ash with the residuum. Surface textures are silty clay, silty clay loam, or medial silt loam.

HALAWA and PUU OPAE soils are Ultisols. The unique properties common to Ultisols are an argillic horizon (containing clay translocated from overlying horizons) and a low supply of bases, particularly in the lower horizons. The cation-exchange capacity in Ultisols is moderate or low. The decrease in base saturation with increasing depth reflects cycling of bases to the surface by plants or additions from fertilizers. In Ultisols that have not been cultivated, the highest base saturation is normally in the few centimeters directly beneath the surface. The clayey horizons can retain substantial amounts of water, much of it available to plants. Ultisols in the suborder Humults, such as these two series, have at least 1.5 percent organic matter in the upper part of the argillic horizon, as defined in the 1972 Soil Survey. Ultisols tend to form in moist climates that promote weathering of soil materials and leaching of base cations, resulting in strongly to extremely acid soils. Many Ultisols in Hawaii are presently in seasonally dry climates; their ultic characteristics formed under wetter ancient climates.

MAHANA soils are Oxisols. Oxisols are more highly weathered than other soils; they have a deep, subsurface oxic horizon dominated by clay-size particles of iron and aluminum hydrous oxides. Plant nutrients have been largely leached out of the soil. At low pH, phosphorus is adsorbed onto the oxides, making it largely unavailable to plants, and the ability to retain cation nutrients such as calcium, magnesium, and potassium against leaching is low. Mahana soils have surface pH of 6.0 or higher, so aluminum toxicity is not a problem and the variable-charge clay-sized particles will have some cation exchange capacity.

OLI soils are Andisols. The volcanic ash soils of Hawaii are derived mostly from basaltic ash that varies relatively little in chemical composition (Hazlett and Hyndman 1996; Vitousek 2004)). Most of these volcanic ash soils are classified today as Andisols, which have these “andic” characteristics: ion exchange capacity that varies with pH, but at the low pH of Oli soils, anion, rather than cation, retention will dominate and base saturation is low; 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 good 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 5. Representative soil features**

| | |
|---|---|
| Parent material | (1) Basic volcanic ash–basalt<br>(2) Residuum–igneous rock |
| Surface texture | (1) Silty clay<br>(2) Medial silt loam<br>(3) Silty clay loam<br>(4) Medial loam |

| | |
|---|---|
| Family particle size | (1) Very-fine<br>(2) Medial<br>(3) Clayey |
| Drainage class | Well drained |
| Permeability class | Very slow to slow |
| Depth to restrictive layer | 30–58 in |
| Soil depth | 30–72 in |
| Surface fragment cover <=3" | 0% |
| Surface fragment cover >3" | 0% |
| Available water capacity (0-40in) | 4–8 in |
| Calcium carbonate equivalent (0-40in) | 0% |
| Electrical conductivity (0-40in) | 0 mmhos/cm |
| Sodium adsorption ratio (0-40in) | 0 |
| Soil reaction (1:1 water) (0-40in) | 4.5–6 |
| Subsurface fragment volume <=3" (0-40in) | 2–3% |
| Subsurface fragment volume >3" (0-40in) | 0% |

**Table 6. Representative soil features (actual values)**

| | |
|---|---|
| Drainage class | Not specified |
| Permeability class | Not specified |
| Depth to restrictive layer | Not specified |
| Soil depth | Not specified |
| Surface fragment cover <=3" | Not specified |
| Surface fragment cover >3" | Not specified |
| Available water capacity (0-40in) | 4–14 in |
| Calcium carbonate equivalent (0-40in) | Not specified |
| Electrical conductivity (0-40in) | Not specified |

| | |
|---|---|
| Sodium adsorption ratio (0-40in) | Not specified |
| Soil reaction (1:1 water) (0-40in) | Not specified |
| Subsurface fragment volume <=3" (0-40in) | Not specified |
| Subsurface fragment volume >3" (0-40in) | Not specified |

## Ecological dynamics

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

Natural Disturbances

There have been no lava flows or heavy volcanic ash flows on this ecological site that are recent enough to have affected the current vegetation and soils. Strong storms may sometimes cause windthrow of trees. Fires started by lightning may rarely affect this ecological site. Drought is increasingly a threat as the climate of the planet changes.

Human Disturbances

Human-related disturbances have been more important than natural disturbances in this ecological site since the arrival of Polynesians and, later, Europeans. This is reflected in the State and Transition Model Diagram.

Humans arrived in the Hawaiian Islands 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 large 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, animals, possibly plant diseases, and wood harvesting. The introduced Pacific rat would have eaten bird eggs, invertebrates, and the seeds of native plants (Athens 1997).

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

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

Through the 20th and into the 21st centuries, increases in human populations with attendant land development, as well as accelerated introduction of non-native mammals (including deer), birds, reptiles, amphibians, invertebrates, plants, and microorganisms, have brought about dramatic changes to wild ecosystems in Hawaii. Much of the original forest of this ecological site was cleared and converted to intensive, irrigated production of sugarcane and pineapple, and the remaining native plant communities have been highly disturbed. Much of the area had been under cultivation, was later abandoned, and then converted to grazing land or urban uses.

## State and transition model

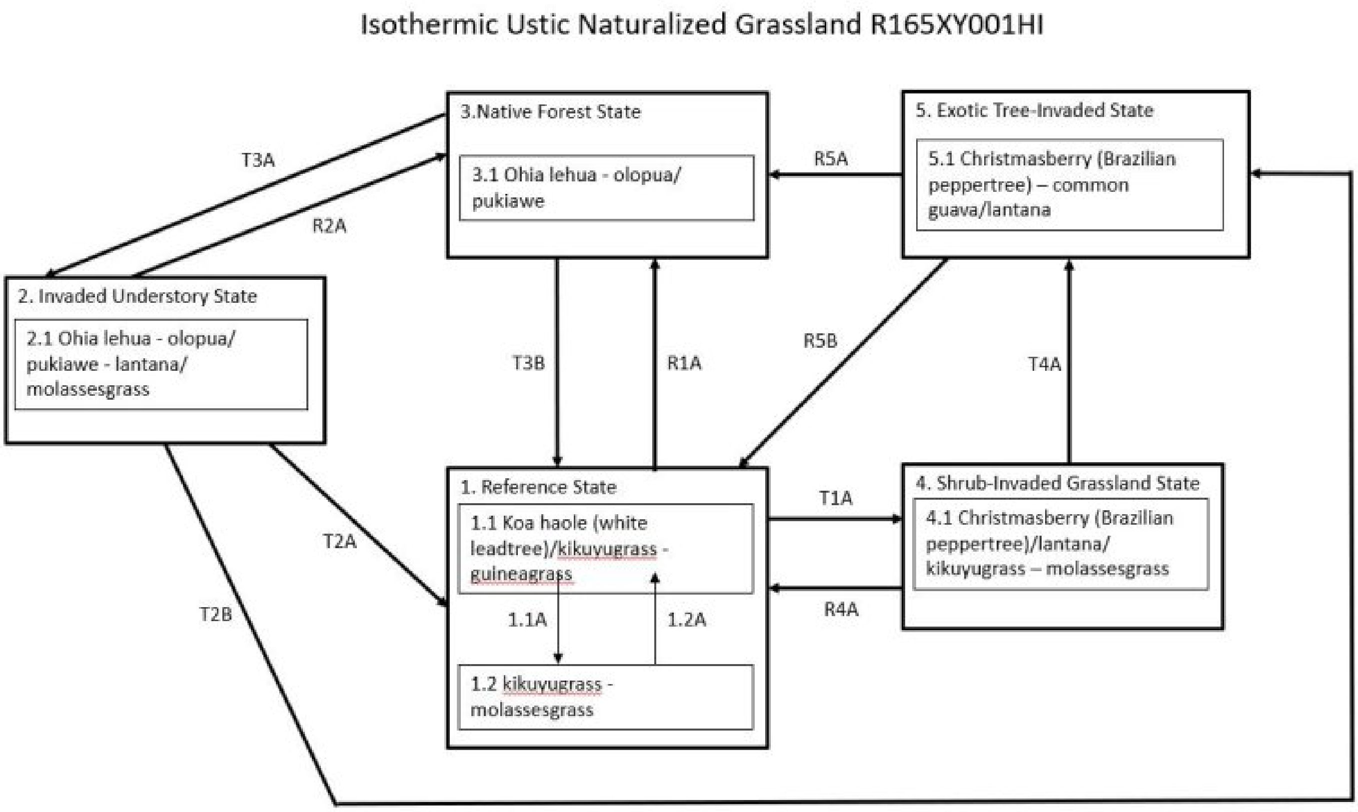


**Figure 7. State and Transition Model for R165XY001HI (Isothermic Ustic Naturalized Grassland)**

## State 1
## Reference State

This state consists of two community phases. It is naturalized grassland with introduced grasses, forbs, and trees. Scattered large trees are sometimes present.

## Community 1.1
## Koa haole (white leadtree)/kikuyugrass-guineagrass

This community phase consists of introduced grasslands dominated by kikuyugrass at the upper elevations of this ecological site and guineagrass at moderate elevations. Buffelgrass may occur at the lowest leeward extremes. Preferred forage species are kikuyugrass, guineagrass, and koa haole, a small leguminous tree. Other forage species are Natal redtop or rose Natal grass (*Melinis repens*) and hilograss (*Paspalum conjugatum*). With continuous heavy grazing, particularly by cattle, preferred forage grasses decrease, as will preferred small trees, vines, and shrubs. Less preferred grass, forb, and shrub species increase under such circumstances. With severe deterioration, shrubby species can increase to eventually dominate.

### Dominant plant species

- white leadtree (*Leucaena leucocephala*), tree
- kikuyugrass (*Pennisetum clandestinum*), grass
- guineagrass (*Urochloa maxima*), grass

## Community 1.2
## Kikuyugrass – molassesgrass

Kikuyugrass and guineagrass are still the most abundant grass species but are now less dominant. Primary increaser grass species that increase under heavy grazing include molassesgrass (*Melinis minutiflora*), feather fingergrass (*Chloris virgata*), wiregrass or Indian goosegrass (*Eleusine indica*), rat-tail grass (Sporobolus africanus syn. S. indicus var. capensis), crabgrass (Digitaria spp.), and Bermudagrass (*Cynodon dactylon*). Unpalatable increaser forbs include sensitive partridge pea (*Chamaecrista nictitans*), sensitive plant or shameplant (*Mimosa pudica*), rattlepod (Crotalaria mucronata), red pualele or lilac tasselflower (*Emilia sonchifolia*), and spiny amaranth (*Amaranthus spinosus*). Shrubby species include lantana (*Lantana camara*), apple of Sodom (Solanum linnaeaum), false mallow (*Malvastrum coromandelianum*), Sacramento bur (*Triumfetta semitriloba*), balloon plant (*Asclepias physocarpa*), christmasberry (*Schinus terebinthifolius*), hairy mallow (Abutilon grandifolia), and castor bean (*Ricinus communis*).

### Dominant plant species

- kikuyugrass (*Pennisetum clandestinum*), grass
- guineagrass (*Urochloa maxima*), grass
- molassesgrass (*Melinis minutiflora*), grass

## Pathway P1.1A
## Community 1.1 to 1.2

Community phase 1.1 converts to phase 1.2 by continuous grazing without adequate rest for preferred forages. This conversion can be avoided by timely application of deferred and/or prescribed grazing to allow recovery of desirable species after grazing or browsing.

## Pathway P1.2A
## Community 1.2 to 1.1

Community phase 1.1 converts to phase 1.2 by continuous grazing without adequate rest for preferred forages. This conversion can be avoided by timely application of deferred and/or prescribed grazing to allow recovery of desirable species after grazing or browsing.

## State 2
## Invaded Understory State

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

### Dominant plant species

- 'ohi'a lehua (*Metrosideros polymorpha*), tree
- Hawai'i olive (*Nestegis sandwicensis*), tree
- pukiawe (*Styphelia tameiameiae*), shrub
- lantana (*Lantana camara*), shrub
- molassesgrass (*Melinis minutiflora*), grass

## Community 2.1
## Ohia lehua - olopua/pukiawe – lantana/molassesgrass

Native tree species dominate the overstory. The understory consists of a variable array of introduced plant species along with remnant native species. The overstory is dominated by ohia lehua, olopua, and other typical native dry forest species such as Hawaii kauilatree (*Alphitonia ponderosa*) and lama (*Diospyros sandwicensis*). Among native shrubs, aalii (*Dodonaea viscosa*) and pukiawe (Leptecophylla tameiameiae) may still be present. The introduced shrub lantana (*Lantana camara*) can be very abundant. The introduced vine huehue haole or corkystem passionflower (*Passiflora suberosa*) can become very abundant, covering the canopies of remnant, low-stature native understory plants.

Introduced grass species are abundant beneath the overstory canopy, which generally is not adequately dense to inhibit their growth. Christmasberry or Brazilian pepper tree (*Schinus terebinthifolius*), an introduced small tree that produces a dense, shady canopy, may be abundant.

#### Dominant plant species

- 'ohi'a lehua (*Metrosideros polymorpha*), tree
- Hawai'i olive (*Nestegis sandwicensis*), tree
- pukiawe (*Styphelia tameiameiae*), shrub
- lantana (*Lantana camara*), shrub
- molassesgrass (*Melinis minutiflora*), grass

### State 3
### Native Forest State

This state consists of one community phase. This description is hypothetical, because very little native vegetation remains in this ecological site. The following description is based on similar ecological sites. The general appearance of this ecological site is an open to nearly closed canopy up to 40 feet (12 meters) tall, an understory of shrubs and small trees, and a ground layer of vines, forbs, and grasses. The canopy becomes shorter and sparser where the forest grades into drier areas near the coast.

### Community 3.1
### Ohia lehua – olopua/pukiawe

The tree canopy is dominated by ohia lehua (*Metrosideros polymorpha*) and typical dry forest species such as olopua (*Nestegis sandwicensis*), lama (*Diospyros sandwicensis*), and ae or Hawaii brushholly (Xylosma hawaiiense). Alahee (*Psydrax odorata*), a small tree or shrub, is common in the understory. Common shrubs are pukiawe (Leptocophylla (Styphelia) tameiameiae), aalii (*Dodonaea viscosa*), ilima (*Sida fallax*), ulei (*Osteomeles anthyllidifolia*), and hillside false ohelo (*Wikstroemia uva-ursi*). Huehue (*Cocculus orbiculatus*) is the most common vine. Native forbs, grasses, and ferns are present but not abundant.

#### Dominant plant species

- 'ohi'a lehua (*Metrosideros polymorpha*), tree
- Hawai'i olive (*Nestegis sandwicensis*), tree
- pukiawe (*Styphelia tameiameiae*), shrub

### State 4
### Shrub Invaded Grassland State

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

## Community 4.1
## Christmasberry (Brazilian peppertree)/lantana/kikuyugrass – molassesgrass

This community is dominated by small trees, shrubs, and grasses. The most common introduced trees present are christmasberry (*Schinus terebinthifolius*) and, if it has not been eliminated by excessive browsing, koa haole (*Leucaena leucocephala*). Lantana (*Lantana camara*) is the most common shrub. Molassesgrass is common between shrubs and beneath koa haole.

### Dominant plant species

- Brazilian peppertree (*Schinus terebinthifolius*), shrub
- lantana (*Lantana camara*), shrub
- kikuyugrass (*Pennisetum clandestinum*), grass
- molassesgrass (*Melinis minutiflora*), grass

## State 5
## Exotic Tree Invaded State

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

## Community 5.1
## Christmasberry (Brazilian peppertree) – common guava/lantana

In many cases, the overstory consists of very dense christmasberry that is 15 to 25 feet (4.5 to 3.25 meters) tall with very little understory. Introduced tree species such as silk oak (*Grevillea robusta*), autograph tree (*Clusia rosea*), kukui (Aleurites moluccana), and octopus tree (*Schefflera actinophylla*) that have greater height potentials than christmasberry may overtop the christmasberry canopy and eventually dominate the site. Remnant, mature ohia lehua (*Metrosideros polymorpha*) trees may be present but are not able to regenerate. Native alahee (*Psydrax odorata*) trees sometimes are able to reproduce and maintain a sparse population in the understory. The overstory composition can be highly variable from site to site, but christmasberry is often the most abundant species. Christmasberry often dominates the understory (<13 feet or 4 meters tall) and can be so dense as to exclude most other species. Where more light is available, the small, introduced trees common guava (*Psidium guajava*) and koa haole (*Leucaena leucocephala*) are common. Lantana (*Lantana camara*) is the most common shrub.

**Dominant plant species**

- Brazilian peppertree (*Schinus terebinthifolius*), tree
- guava (*Psidium guajava*), tree
- lantana (*Lantana camara*), shrub

## Restoration pathway R1A
## State 1 to 3

It is possible to restore State 1 Reference to a plant community resembling State 3 Native Forest. Weed control must be applied to forage species and the many opportunistic plant species that would invade the site. Weed control would be a perpetual process to maintain the site. Fire must be excluded. Domestic and feral ungulates must be excluded by a suitably designed and maintained fence. Extensive planting of native species would follow.

## Transition T1A
## State 1 to 4

State 1 Reference transitions to State 4 Shrub Invaded Grassland through further overgrazing or abandonment. Fire will temporarily prevent this transition. Koa haole will be greatly reduced by over browsing. If the site contained abundant koa haole and was then abandoned, these small trees can greatly increase in abundance. Otherwise, there is gradual invasion by weedy shrubs and small trees.

## Transition T2A
## State 2 to 1

State 2 Invaded Understory transitions to State 1 Reference by land clearing with heavy machinery followed by weed control. Land clearing can promote germination of the weed seed bank in the soil, requiring weed control. After clearing and weed control, the site would be planted to forage species.

## Restoration pathway R2A
## State 2 to 3

State 2 Invaded Understory may be restored to a facsimile of State 3 Native Forest State, by removal of the introduced understory through weed control measures. Reintroduction of native understory species is required. The site must be fenced securely to exclude ungulates.

## Transition T2B

### State 2 to 5

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

### Transition T3B
### State 3 to 1

State 3 Native Forest transitions to State 1 Naturalized Grassland by clearing the forest and planting desirable forage species.

### Transition T3A
### State 3 to 2

State 3 Native Forest State transitions to State 2 Invaded Understory through grazing, browsing, rooting, and trampling by domestic or feral ungulates (cows, sheep, deer, goats, and pigs). These activities destroy small native plant species and seedlings and saplings of large species. Regeneration of the native forest is prevented, leading to tree populations consisting almost entirely of mature plants. Lack of competition from native plants, introduction of weed seeds, and disturbance of the soil lead to an understory dominated by introduced plant species. Weeds can invade intact native forest even in the absence of ungulates and gradually bring about the transition. Invasive vines, shrubs, and small trees will grow under intact native canopies and begin to degrade the forest. Eventually, introduced grasses provide fine fuels that can carry intense fires that destroy the native tree canopy.

### Restoration pathway R4A
### State 4 to 1

State 4 Exotic Tree Invaded State can be restored to State 1 Reference by brush management with follow-up control of re-sprouting shrubs and emerging weedy forbs. Forage species may be replanted and maintained by prescribed grazing.

### Transition T4A
### State 4 to 5

State 4 Shrub Invaded Grassland transitions to State 5 Exotic Tree Invaded with lack of fire. Fast-growing introduced tree species invade Shrub Invaded Grassland and overtop shrubs, or christmasberry increases in stature and density to become dominant.

### Restoration pathway R5B
### State 5 to 1

State 5 Exotic Tree Invaded State may be restored to State 1 Reference. Total clearing of the site would be necessary. If clearing is done by heavy machinery, soil disturbance would occur. This would probably induce germination of the weed seed bank and also increase the potential for soil erosion. Weed control and brush management must then be applied multiple times to control new weed germination and resprouting. After clearing and weed control, the site would be planted to forage species. Ungulates must be excluded until forages are well established; prescribed grazing must then be applied.

### Restoration pathway R5A
### State 5 to 3

It may be possible to restore State 5 Exotic Tree Invaded to a community resembling State 3 Native Forest. Total clearing of the site would be necessary. Alternatively, it may be worthwhile to kill taller weed species in place in order to provide some shelter for the ground. If clearing is done by heavy machinery, soil disturbance would occur. This could induce germination of the weed seed bank and also increase the potential for soil erosion. Weed control would be ongoing. Protection from fire is needed, and ungulates must be excluded by a suitable fence.

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DEFINITIONS

Aa lava: A type of basaltic lava having a rough, jagged, clinkery surface and a vesicular interior.

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.

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

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

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

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

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

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

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

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

Ion exchange capacity: The ability of soil materials such as clay or organic matter to retain ions (which may be plant nutrients) and to release those ions for uptake by roots.

Isothermic soil temperature regime: A regime in which mean annual soil temperature is 59 degrees F (15 degrees C) or higher but lower than 72 degrees F (22 degrees C) and mean summer and mean winter soil temperatures differ by less than 11 degrees F (6 degrees C) at a specified depth.

Major Land Resource Area (MLRA): A geographic area defined by NRCS that is characterized by a particular pattern of soils, climate, water resources, and land uses. The island of Hawaii contains nine MLRAs, some of which also occur on other islands in the state.

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.

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

Pahoehoe lava: A type of basaltic lava with a smooth, billowy, or rope-like surface and vesicular interior.

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

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.

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

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

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

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

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

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

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

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

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

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

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

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

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## Rangeland health reference sheet

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

| | |
|---|---|
| Author(s)/participant(s) | |
| Contact for lead author | |
| Date | 05/21/2025 |
| Approved by | Kendra Moseley |

| | |
|---|---|
| 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:**