# Executive Summary - Tucker 2

**Introduction**

Rebellion Energy Solutions and SnapLands have been partnered since 2023 to ensure that their orphan well plugging efforts are followed by ecological restoration and the revival of native prairie landscapes. One site in particular, Tucker 2, which prior to the well plugging and restoration efforts was a dense stand of Eastern Red Cedar (*Juniperus virginiana)* trees, has been undergoing continued management, restoration inputs, and maintenance since the fall of 2023.

**Figure 1.** *Initial site assessment of Tucker 2 Orphan Well found in dense stand of Eastern Red Cedar.*

Across the Southern Great Plains, particularly in Oklahoma, rangelands are undergoing a drastic ecological shift, from native grasslands to woody-dominated landscapes. At the center of this transformation is the unchecked spread of *Juniperus virginiana*, commonly known as Eastern Red Cedar. Once limited by natural cycles of fire and grazing, this evergreen juniper species has rapidly proliferated due to fire suppression and land management changes. The consequences are profound. Experimental data at the watershed level show that as rangelands convert to Eastern Red Cedar woodlands, streamflow is significantly reduced (Impact of Eastern Red Cedar on Water Resources)**.** These trees consume large quantities of water, outcompeting native grasses and reducing groundwater recharge. This has cascading effects on agricultural productivity, livestock forage availability, collapsing biodiversity of our prairies and overall land value. For every 10% increase in cedar cover, 400 lbs./acre of forage are lost (Cedar Coverage Reduce Forage). In addition, more Lonestar ticks infected with Ehrlichia or Rickettsia are most common in cedar woodlands while grasslands are least likely to have ticks infected with these pathogens.(Eastern Red Cedar and Tick Pathogens) Economically, the encroachment of Eastern Red Cedar is estimated to cost the state of Oklahoma hundreds of millions of dollars annually. Lost grazing potential, increased wildfire risk, and the growing expense of mechanical or chemical removal place a heavy burden on both private landowners and public agencies. It is estimated that Oklahoma is losing 300K acres per year (Juniper Biomass) due to juniper encroachment and if left unmanaged, the continued expansion of Eastern Red Cedar threatens not only the ecological health of Oklahoma's rangelands, but the livelihoods of those who depend on them.

The purpose of this report is to:

1. Share the data collection results from the **treatment** site and compare those to data collected at the **control** site located in the adjacent stand of Eastern Red Cedar (*Juniperus virginiana*) trees.
2. Share the methods of management, inputs, and maintenance at the Tucker 2 site.

**Methods**

In 2023, Rebellion Energy Solutions cut down and chipped an area of approximately one acre of Eastern Red Cedar trees around the orphaned well site. The mulch chips were then spread across the open area to cover the bare ground. SnapLands drill-seeded a diverse mix of 28 cover crops consisting of legumes, grasses, and forbs in 2024, with 14 cool-season species seed in February, and 14 warm-season species in April. These cover crops were intended to improve soil health and add organic matter to the soil surface prior to native seeding. Due to the rapid and vigorous growth of vegetation, a mowing treatment was completed in February of 2025 followed by the drill-seeding of a highly diverse and dense native seed mix consisting of 36 different grasses, legumes, and forbs (see full species list in appendix). In August of 2025, cedar tree seedlings that were found in the restoration area were clipped or pulled in order to prevent encroachment. No herbicides, pesticides, or other chemical inputs were used in the restoration of this site.

In May of 2024 and June of 2025, SnapLands completed LandEKG™ monitoring, a methodology that assesses 21 land health indicators to yield an ecological function score, collects timelapse photography, and reads soil cover and plant community composition within two hoops along a fixed transect (see appendix for more detail on methodology). This methodology was completed in both the restoration and control areas. Soil and forage samples were taken from the control and treatment areas in June of 2025 to assess forage and soil health, and soil bulk density. The Comprehensive Assessment of Soil Health (CASH) was completed through the Cornell Soil Health Lab. A full species inventory of all plants found within the treatment and control areas was also completed at this time.

**Findings**

In 2025, the LandEKG Ecological Function™ score was 51/100 in the control area, and 71/100 in the treatment area, representing a 39% increase in ecological function in the treated area. There were 105 plant species identified in the treatment area compared to 10 species in the control (see full species list in appendix). This represents a **950%** increase in species diversity after less than two years from removal of the Eastern Red Cedar and implementation of the restoration plan. 32 of the 105 plant species in the treatment area originated from the native seed mix that was planted. Of the plant species identified in the treatment site, 83 were native to the region. Of the non-native plants, all but 6 are annuals or biennials that should fade out of the site over time as the perennial plant community develops.

Between 2024 and 2025, the LandEKG™ readings within monitoring hoops showed an increase in grass species from 1 to 5, and forb species increased from 6 to 10. Species identified within these hoops in 2024 were largely cover crops which were then replaced by more desirable native species in 2025. Both hoop locations happened to contain abnormally thick cedar mulch which may have affected germination rates. Very high litter cover was recorded in both the treatment and control areas.

The transect photos in **Figure 2, Figure 3, and Figure 4** were taken in 2024 to 2025 and show that germination and perennial establishment has expanded across the treatment site over time, while no understory encroachment of seeded plants was observed on the control site.

**Figure 2.** *Two images showing the **treatment** short line transect photo in 2024 (left) and 2025 (right).*

**Figure 3.** *Two images showing the **treatment** long line transect photo in 2024 (left) and 2025 (right).*

**Figure 4.** *Two images showing the **control** long line transect photo in 2024 (left) and 2025 (right).*

Soil samples were collected in 2025 at the treatment and control sites, allowing for comparisons to be presented for carbon content, soil moisture, bulk density, predicted available water capacity, organic matter, soil respiration, and soil pH (see appendix for full results). **Total carbon in the treatment area was 4.171% compared to 2.66% in the control**. Soil moisture was 39.7% in the treatment vs 21.7% in the control site. The soil from the control was twice as dense as the soil from the treatment. During sampling it was noted that the treatment site had poor soil structure and contained large air pockets throughout, possibly resulting in the difference of density between the two. This poor soil structure may be due to the soil disturbance that occurred with the initial removal of the Eastern Red Cedar.

The Cornell Soil Health Lab's Comprehensive Assessment of Soil Health (CASH) rates a series of soil health indicators on a scale from 1-100. For more information on these indicators visit the CASH website: https://soilhealthlab.cals.cornell.edu/. The overall CASH soil quality score for the treatment site was 85 compared to the control of 72. Predicted available water capacity was 93 for the treatment and 85 for the control. The soil respiration at the treatment was 79 and 59 at the control. Aggregate stability results for the treatment scored 38 and the control scored 74, a result which is likely linked to the previously mentioned poor soil structure within the treatment site. There was a noticeable difference in the rating for soil pH at the treatment, which was 98 (more ideal for plant health), while the control had a rating of 1 (very acidic). The low pH at the control site is likely due to the high acidity of Eastern Red Cedar needle accumulation and will greatly reduce nutrient availability to plants, constraining proper soil functioning, decreasing root growth, and influencing the ability of beneficial organisms to colonize the roots.

Forage production in pounds per acre (lbs/acre) was assessed by taking clippings from the treatment and control sites. The control site did not have any understory forage to clip and thus had 0 lbs/acre. Two forage clippings were taken from the treatment site, one in a dense growth area and the second in a sparse growth area, with an average of 936 lbs/acre. We could expect the whole treatment site to meet or exceed the denser sampling area after a few more years of establishment with production of closer to 2,500-3,000 lbs/acre. Ecological Site Description data from the USDA's Natural Resources Conservation Service supports these assumptions.

**Conclusion**

Through restorative inputs, careful management, and continued maintenance at the Tucker 2 restoration site, SnapLands has been able to promote the growth of native grasses, forbs, and legumes in an area that was formerly grassland prior to the rapid encroachment of Eastern Red Cedar that began in the late 1900's. By managing to keep the treatment area clear of cedar encroachment, planting diverse and dense seed mixes, and performing routine maintenance, we are allowing the diversity of native grasses, forbs, and legumes to persist and resist the landscape reverting back to a monoculture of Eastern Red Cedar.

The treatment has current and future potential to directly and indirectly benefit many wildlife and pollinator species (see appendix for a more detailed list of species affected). Of particular note is the Monarch Butterfly which will be directly affected by the provision of food sources, host plants, and quality habitat through the milkweed (*Asclepias* spp.) species and many favored nectar-producing forbs planted. Many other species such as wetland birds will reap positive indirect benefits from the water retention abilities of the soil in the treatment area. Through increased water retention and reduced erosion, runoff and downstream contamination of local streams will be lessened. Lastly, grassland birds, which are greatly impacted by habitat loss across most of their range, stand to gain some habitat and seed forage availability from the treatment site.

If Rebellion Energy Solutions had chosen to forgo any restoration management and inputs and instead concluded work after spreading the cedar mulch, some native plant species would have colonized the newly cleared area on their own, but the diversity would have been lower, and the cedar trees would eventually move back onto the site. This highlights the importance of continued management of cedar trees, with the restoration inputs being key components of restoration progress. Continued management to promote persistence of grassland habitat could include grazing, hand-clipping, and prescribed burning.

# Tucker 2 Restoration Pictures

**Figure 5.** September 2023 picture showing the planned restoration area where Eastern Red Cedar were cut down, chipped, and the mulch was spread throughout.

**Figure 6.** May 2024, 3 months following the first phase cover crop seeding, and 1 month following the second phase of cover crop seeding.

**Figure 7.** August 2024, 6 months following the first phase of cover crop seeding, and 4 months following the second phase of cover crop seeding.

**Figure 8.** June 2025, 16 months following the first phase of cover crop seeding, 14 months following the second phase of cover crop seeding, and 4 months following the first phase of native seeding.

# APPENDIX

# Tucker 2 Anticipated Results

These photos were taken by SnapLands Ecological Restorationist Skyler Smith at the Joseph H. Williams Tallgrass Prairie Preserve which is operated and was restored by The Nature Conservancy. These images contain plant communities that are representative of the seed mixes put together by the SnapLands restoration team and are meant to convey desired results of restoration efforts after several years of establishment have commenced.

# Tucker 2 Historical Satellite Images

Shown below are satellite imagery of the Tucker 2 site beginning in February 1995 and concluding with the most recent satellite imagery available from November 2024 showing rapid expansion over those years due to land use changes. This same expansion is common across many areas of the state.

February 1995


October 2004

September 2016


November 2024

## Critical Habitat Planted in February 2025

### Native Seed Mix for Tucker 2

| Species | Functional Group | % of Total Seed Mix | Benefits |
|---|---|---|---|
| Big Bluestem - Andropogon gerardii | Warm Season Grass | 8.04% | Native prairie grasses provide soil stabilization, carbon sequestration through deep, frequently shed root systems and sugar exudates. Host species for many species of butterfly larvae. Habitat structure for prairie birds, seeds are a food source for many songbirds. Forage for many grazing mammals and nest material for birds and small mammals. |
| Sideoats Grama - Bouteloua curtipendula | Warm Season Grass | 16.08% | |
| Switchgrass - Panicum virgatum | Warm Season Grass | 8.04% | |
| Indiangrass - Sorghastrum nutans | Warm Season Grass | 12.06% | |
| Little Bluestem - Schizachyrium scoparium | Warm Season Grass | 12.06% | |
| Leadplant - Amorpha canescens | Legume | 1% | The root nodules of legumes interact with mycorrhizal bacteria in the soil to fix nitrogen and allow it to be used by other plants in the community. The native legumes chosen for this list are all very high-protein forage for grazing animals. The flowers of legume species are also a valuable nectar source for many native pollinator species. |
| Partridge Pea - Chamaecrista fasciculata | Legume | 4.02% | |
| Purple Prairie Clover - Dalea purpurea | Legume | 4.02% | |
| Prairie Bundleflower - Desmanthus illinoesnsis | Legume | 4.02% | |
| Showy Tick Trefoil - Desmodium illinoense | Legume | 2.01% | |
| Bush Clover -Lespedeza capitata | Legume | 2.01% | |
| Butterfly Milkweed - Asclepias tuberosa | Forb | 2.01% | Species in the Milkweed genus are vital host plants for Monarch Butterflies and are the only food the caterpillars will eat. Adults mate and lay eggs directly on the plant and young spend their whole life cycle through pupation there. Also valuable nectar sources for many pollinators. |
| Common Milkweed - Asclepias syriaca | Forb | 2.01% | |
| False Aster - Boltonia asteroides | Forb | 1% | Nectar source for many native pollinators including butterflies, long and short-tongued bees, wasps, flies, skippers, moths, and beetles. |
| Plains Coreposis - Coreopsis tinctora | Forb | 1% | Nectar source for a wide variety of pollinating insects. |
| Pale Prairie Coneflower - Echinacea pallida | Forb | 2.01% | Important early-season nectar source for a wide range of pollinating insects and hummingbirds. Host plant to various Skipper butterfly species. |
| Purple Prairie Coneflower - Echinacea purpurea | Forb | 2.01% | Nectar source for a wide variety of pollinating insects. Many birds such as American goldfinches feed on seeds. |
| Rattlesnake Master - Eryngium yuccifolium | Forb | 1.00% | Nectar source for many small species of native bees, flies, and moths. Host plant for the Black Swallowtail butterfly. |
| Maximilian Sunflower - Helianthus maximiliani | Forb | 2.01% | Nectar source to a number of long-tongued bees, short-tongued bees, butterflies, and moths. Larval host species of the Bordered Patch butterfly. |
| Prairie Blazingstar - Liatris pychnostachya | Forb | 1.00% | Important favorite nectar source for Monarch Butterflies as well as many other species of pollinating insects and hummingbirds. |
| Blue Flax - Linum lewisii | Forb | 1.00% | Early-season nectar source for many pollinators when few other plants have begun to bloom. |
| Beebalm - Monarda fistulosa | Forb | 1.00% | Favorite nectar source for many native bumblebees. Hummingbirds and butterflies are also attracted to this plant. |
| Stiff Goldenrod - Oligoneuron rigidum | Forb | 1.00% | Important late season nectar source for many pollinating insects, particularly bees and wasps. |
| Foxglove Beardtongue - Penstemon digitalis | Forb | 1.00% | Nectar source for many long-tongued bees, hummingbirds, and butterflies. |
| Grey Headed Coneflower - Ratibida pinnata | Forb | 1.00% | Long-blooming nectar source for a wide variety of pollinating insects through mid-summer. Seeds feed birds through fall and winter. |
| Black-Eyed Susan - Rudbeckia hirta | Forb | 2.01% | Nectar source for a wide variety of pollinating insects. |
| Blue Pitcher Sage - Salvia azurea | Forb | 0.50% | Late-season nectar source for hummingbirds, butterflies, and long-tongued bees. Host species to the Hermit Sphinx Moth. |
| Compass Plant - Silphium laciniatum | Forb | 1.00% | Extremely long-lived and deep-rooted plant that aids in soil stabilization and carbon sequestration. Nectar source for many pollinators. Seeds feed birds through fall and winter. |
| Smooth Blue Aster - Symphyotrichum laeve | Forb | 1.00% | Late-season nectar source for a wide variety of pollinators. Host plant for the Silvery Checkerspot and the Pearl Crescent butterflies. |
| Hoary Vervain - Verbena stricta | Forb | 1.00% | Long-blooming nectar source for a wide variety of pollinating insects through mid-summer. Seeds feed birds and small mammals through fall and winter. Larval host for the Common Buckeye Butterfly. |
| Common Ironweed - Vernonia fasiculata | Forb | 1.00% | Nectar source for a large variety of native bees and butterflies. Host species to Parthenice Tiger Moth, Red Groundling, and Ironweed Borer Moth. |
| Golden Alexanders - Zizia aurea | Forb | 1.00% | Nectar source for many small species of native bees, flies, and moths. Host plant for the Black Swallowtail butterfly. |

Tucker 2 Treatment Site Plant Inventory June 6, 2025 **BOLD = Component of Seeded Mix**

Native Grasses/Sedges/Rushes

*Andropogon gerardii* - **Big Bluestem**
*Andropogon virginicus* - Broomsedge Bluestem
*Bouteloua curtipendula* - **Sideoats Grama**
*Carex bushii* - Bush's Sedge
*Carex meadii* - Mead's Stiff Sedge
*Cyperus echinatus* - Globe Flatsedge
*Eleocharis compressa - Flatstem Spikerush*
*Elymus canadensis* - **Canada Wildrye**
*Juncus dudleyi* - Dudley's Rush
*Panicum virgatum* - **Switch Grass**
*Schizachyrium scoparium - Little Bluestem*
*Scleria pauciflora* - Few-Flowered Nutrush
*Sorghastrum nutans* - **Indiangrass**
*Sporobolus compositus* - Tall Dropseed

Native Perennial Forbs

*Achillea millefolium* - Common Yarrow
*Ambrosia psilostachya* - Ragweed
*Amorpha canescens* - **Leadplant**
*Apocynum cannabinum* - Dogbane
*Asclepias viridis* - Green Milkweed
*Baptisia australis* - **Blue Wild Indigo**
*Baptisia sphaerocarpa* - Cream Wild Indigo
*Boltonia asteroides* - **False White Aster**
*Cirsium altissimum* - Tall Thistle
*Dalea purpurea* - **Purple Prairie Clover**
*Desmanthus illinoensis* - **Prairie Bundleflower**
*Desmodium illinoense* - **Showy Tick Trefoil**
*Echinacea pallida* - **Pale Prairie Coneflower**
*Echinacea purpurea* - **Purple Coneflower**
*Eupatorium altissimum* - Tall Boneset
*Eupatorium capillifolium* - Dogfennel
*Euthamia gymnospermoides* - Grass-leafed Plains Goldenrod
*Geranium carolinianum* - Wild Geranium
*Geum macrophyllum* - Large-leafed Avens
*Helianthus maximilliani* - **Maximillian Sunflower**
*Lespedeza capitata* - **Round-headed Bushclover**
*Liatris pychnostachya* - **Prairie Blazingstar**
*Linum lewisii* - **Prairie Flax**
*Monarda fistulosa* - **Beebalm**
*Oenothera macrocarpa* - **Missouri Evening Primrose**
*Oligoneuron rigidum* - **Stiff Goldenrod**
*Oxalis violacea* - Violet Woodsorrel
*Passiflora incarnata* - Maypop Passionflower
*Penstemon digitalis* - **Foxglove Beardtongue**
*Psoralidium tenuiflorum* - Slimflower Scurfpea
*Ratibida pinnata* - **Grey-headed Coneflower**
*Ruellia humilis* - Wild Petunia
*Salvia azurea* - **Blue Pitcher Sage**
*Scutellaria parvula* - Small Scullcap
*Silphium laciniatum* - **Compassplant**
*Solidago missouriensis* - Missouri Goldenrod
*Solidago rugosa* - Rough Goldenrod
*Teucrium canadense* - Canada Germander
*Verbena stricta* - **Hoary Verbena**
*Vernonia baldwinii* - **Western Ironweed**
*Zizia aurea* - **Golden Alexanders**

Native Annual Forbs

*Bidens aristosa* - Showy Tickseed
*Chamaecrista fasciculata* - **Partridge Pea**
*Chenopodium album* - Lamb's Quarters
*Conyza canadensis* - Horseweed
*Coreopsis tinctoria* - **Plains Coreopsis**
*Croton capitatus* - Woolly Croton
*Dichanthelium scribnerianum* - Scribner's Panicgrass
*Erigeron strigosus* - Annual Fleabane
*Euphorbia dentata* - Toothed Spurge
*Euphorbia maculata* - Prairie Sandmat
*Gaillardia aristata* - **Indian Blanketflower**
*Helianthus annuus* - Annual Sunflower
*Monarda citriodora* - **Lemon Beebalm**
*Oxalis dillenii* - Southern Woodsorrel
*Panicum capillare* - Witchgrass
*Plantago virginica* - Hoary Plantain
*Rudbeckia hirta* - **Black-eyed Susan**
*Trichostema coeruleua* - Blue Pennyroyals

Native Trees/Shrubs

*Cersis canadensis* - Eastern Redbud
*Diospyros virgianiana* - Persimmon
*Fraxinus albicans* - Texas Ash
*Juniperus virginiana* - Eastern Red Cedar
*Platanus occidentalis* - Sycamore
*Quercus maralandica* - Blackjack Oak
*Quercus stellata* - Post Oak
*Rhus glabra* - Smooth Sumac
*Rubus trivialis* - Southern Dewberry
*Symphoricarpos orbiculatus* - Coralberry

Non-Native

*Bromus japonicus* - Japanese Brome
*Bromus tectorum* - Cheatgrass
*Carduus nutans* - Musk Thistle
*Cerastium arvense* - Field Chickweed
*Cichorium intybus* - Chicory
*Daucus carrota* - Queen Anne's Lace
*Festuca arundinacea* - Tall fescue
*Lactuca serriola* - Prickly Lettuce
*Melilotus officinalis* - Yellow Sweetclover
*Poa pratensis* - Kentucky Bluegrass
*Portulaca oleracea* - Purslane
*Sericea lespedeza* - Chinese Bushclover
*Sonchus oleraceus* - Sow Thistle
*Sorghum halpense* - Johnson grass
*Stellaria media* - Chickweed
*Taraxacum officinale* - Dandelion
*Tragopogon dubius* - Salsify
*Trifolium repens* - White Clover
*Ulmus pumila* - Siberian Elm

Remnant Cover Crops

*Trifolium incarnata* - Crimson Clover
*Brassica* sp. - Mustard
*Vicia sativa* - Common Vetch
*Triticum aestivum* - Cereal Rye

## Threatened and Endangered Species List: Nowata & Washington County, Oklahoma

### Tucker 2

| Species | Scientific Name | Species type | Habitat | Federal Status | State Status | Relevant Threats |
|---|---|---|---|---|---|---|
| Alligator snapping turtle | Macrochelys temminckii | Reptile | Semi-aquatic | Proposed Threatened | Imperiled | Poor agricultural practices including frequent tilling, pesticide and fertilizer use, and lack of perennial plant erosion buffers often lead to water pollution and erosion that can result in a damaged food chain and otherwise degraded habitat. Researchers (Riedel et al.)noted a drastic decline of alligator snapping turtles in Oklahoma, due in part to habitat degradation because of stream channelization. |
| American burying beetle | Nicrophorus americanus | Insect | Non-specialist. Woodland, grassland, pasture | Threatened | Critically Imperiled | Reasons for decline are not well understood, but habitat fragmentation/alteration, human activity, light pollution, disease, competitors, and pesticides are all possible contributing factors. Soil quality may be important for the species' need to bury carrion for larval success. No specific plants have been identified as critical to the success of this species, though general improvement of habitat and ecosystems may assist in its ability to thrive. |
| Gray bat | Myotis grisescens | Mammal | Old-growth forest/Forest Edge | Endangered | Critically Imperiled | Largest declines have been a result of loss of cave habitat to human use/improper gating. White-Nose Syndrome (WNS) has been detected in the species but has not yet posed a serious threat. Loss of insect prey base due to pesticide/herbicide use and conversion of prairie into cropland has likely led to population declines as well. Of these threats, the most impact our work could potentially have is by increasing the flowering plants that flying insects feed on, thus increasing food populations for the bats. All flowering species, including grasses, within our restoration plans feed various insects and are shown to aid in the increase of both populations and biodiversity of insects. |
| Monarch butterfly | Danaus plexippus | Insect | Prairie/Woodland | Candidate | NA | Uses Oklahoma prairie habitat as part of its summer breeding range. Declines have mostly been a result of loss of its host species plant - Milkweed (*Asclepias* spp.) due to change of land use into crops - mostly Round-up ready corn and soybeans. Young monarch caterpillars exclusively eat plants in the *Asclepias* genus and therefore may benefit from addition of this plant to all prairie restoration projects. |
| Neosho Mucket | Lampsilis rafinesqueana | Freshwater Mussel | Aquatic | Endangered | Critically Imperiled | Most impacted by habitat loss as a result of channeling, gravel mining, other invasives (zebra mussels), habitat fragmentation, harmful agricultural practices, and climate change. Runoff of fertilizer and pesticides and major problems resulting in eutrophication and toxicity respectively. Major impacts that our project may be able to mitigate are agricultural practices that lead to siltation and runoff, both of which may be reduced by strong perennial plant communities which decrease erosion, particularly native grasses. Climate change impacts may be generally mitigated by planting large swaths of native plant communities that sequester carbon and prevent CO2 out-gassing through tillage. Specific species likely to most aid in this mitigation are *Andropogon gerardii, Panicum virgatum, Sorghastrum nutans,* and *Schizachyrium scoparium.* |
| Northern Long-Eared Bat | Myotis septentrionalis | Mammal | Old-growth forest/Forest Edge | Threatened | Imperiled | Primary causes of decline are fungal disease known as White Nose Syndrome (WNS), mortality caused by wind turbines, loss of forest habitat, and food insect population declines. Of these, the most impact our work could potentially have is by increasing the flowering plants that flying insects feed on, thus increasing food populations for the bats. All flowering species, including grasses, within our restoration plans feed various insects and are shown to aid in the increase of both populations and biodiversity of insects. |
| Piping Plover | Charadrius melodus | Bird | Shoreline/Marsh | Threatened | NA | Similar to other shore nesting birds, Piping Plovers require relatively undisturbed shoreline habitat along rivers, reservoirs, lakes, and marshes. Disturbance by humans, cattle, and predators drastically reduces hatchling survival. Good water quality can be improved by planting 10% or more of croplands and disturbed industrial sites as native, perennial plant communities. This helps to avoid erosion, pollution/fertilizer, and pesticide runoff |
| Rabbitsfoot | Quadrula cylindrica cylindrica | Freshwater Mussel | Aquatic | Threatened | Critically Imperiled | Most impacted by habitat loss as a result of channeling, gravel mining, other invasives (zebra mussels), habitat fragmentation, harmful agricultural practices, and climate change. Runoff of fertilizer and pesticides and major problems resulting in eutrophication and toxicity respectively. Major impacts that our project may be able to mitigate are agricultural practices that lead to siltation and runoff, both of which may be reduced by strong perennial plant communities which decrease erosion, particularly native grasses. Climate change impacts may be generally mitigated by planting large swaths of native plant communities that sequester carbon and prevent CO2 out-gassing through tillage. Specific species likely to most aid in this mitigation are *Andropogon gerardii, Panicum virgatum, Sorghastrum nutans,* and *Schizachyrium scoparium.* |
| Red knot | Calidris canutus rufa | Bird | Shoreline/Marsh | Threatened | Critically Imperiled | Mostly impacted by coastal issues including habitat degredation, food source reduction (horseshoe crab eggs), and pollution. Uses OK as a migratory route and relies on herbaceous marshland of good quality. Fewer than 5 birds are usually reported in the state annually and nearly all are seen passing through during fall migration. |
| Tricolored bat | Perimyotis subflavus | Mammal | Old-growth forest/Forest Edge | Proposed Endangered | Vulnerable | Primary causes of decline are fungal disease known as White Nose Syndrome (WNS), mortality caused by wind turbines, loss of forest habitat, and food insect population declines. Of these, the most impact our work could potentially have is by increasing the flowering plants that flying insects feed on, thus increasing food populations for the bats. All flowering species, including grasses, within our restoration plans feed various insects and are shown to aid in the increase of both populations and biodiversity of insects. |
| Western fanshell | Cyprogenia aberti | Freshwater Mussel | Aquatic | Proposed Threatened | NA | Most impacted by habitat loss as a result of channeling, gravel mining, other invasives (zebra mussels), habitat fragmentation, harmful agricultural practices, and climate change. Runoff of fertilizer and pesticides and major problems resulting in eutrophication and toxicity respectively. Major impacts that our project may be able to mitigate are agricultural practices that lead to siltation and runoff, both of which may be reduced by strong perennial plant communities which decrease erosion, particularly native grasses. Climate change impacts may be generally mitigated by planting large swaths of native plant communities that sequester carbon and prevent CO2 out-gassing through tillage. Specific species likely to most aid in this mitigation are *Andropogon gerardii, Panicum virgatum, Sorghastrum nutans,* and *Schizachyrium scoparium.* |

# SOIL HEALTH REPORTS

**Account No. :** 19652

# Soil Analysis Report

WHITE, RYAN
SNAPLANDS LLC
7215 EGYPTIAN DR
FORT COLLINS CO 80525

**Invoice No. :** 1448174
**Date Received :** 06/11/2025
**Date Reported :** 06/13/2025

**Results For :** TUCKER 2
**Location :** TK2

| | |
|---|---|
| **Lab No. :** 801668 | **Depth :** 0 - 6 |
| **ID :** T-101 | |

| | |
|---|---|
| **Calcium Carbonate, %** | 0.0 |
| **Total Carbon, % C** | 4.171 |
| **Saturated Soil Paste Analysis (SAR)** | |
| **Total Dry Weight, g** | 278.73 |
| **Rocks, grams** | 0.10 |
| **Rocks Volume, $cm^3$** | 0.10 |
| **Rocks Density, $g/cm^3$** | 1.00 |
| **Roots, grams** | 0.47 |

| Soil Texture | Sand, % | Silt, % | Clay, % |
|---|---|---|---|
| Clay Loam | 33 | 31 | 36 |

**Reviewed By :** Nick Ward **7/21/2025** **Copy : 1** **Page 1 of 4**

Bus: 308-234-2418
Fax: 308-234-1940
web site
www.wardlab.com
4007 Cherry Ave., P.O. Box 788
Kearney, Nebraska 68848-0788

**Account No. :** 19652

# Soil Analysis Report

**WHITE, RYAN**
**SNAPLANDS LLC**
**7215 EGYPTIAN DR**
**FORT COLLINS** **CO** **80525**

**Invoice No. :** 1448174
**Date Received :** 06/11/2025
**Date Reported :** 06/13/2025

**Results For :** TUCKER 2
**Location :** TK2

| | |
|---|---|
| **Lab No. :** 801669 | **Depth :** 0 - 6 |
| **ID :** T-102 | |
| **Calcium Carbonate, %** | 0.0 |
| **Total Carbon, % C** | 2.660 |
| **Saturated Soil Paste Analysis (SAR)** | |
| **Total Dry Weight, g** | 266.59 |
| **Rocks, grams** | 0.03 |
| **Rocks Volume, $cm^3$** | 0.10 |
| **Rocks Density, $g/cm^3$** | 3.33 |
| **Roots, grams** | 0.21 |

| Soil Texture | Sand, % | Silt, % | Clay, % |
|---|---|---|---|
| Loam | 47 | 35 | 18 |

**Reviewed By :** Nick Ward **7/21/2025** **Copy : 1** **Page 3 of 4**

**Account No. :** 19652

**Soil Analysis Report**

WHITE, RYAN
SNAPLANDS LLC
7215 EGYPTIAN DR
FORT COLLINS CO 80525

**Invoice No. :** 1448174
**Date Received :** 06/11/2025
**Date Reported :** 06/13/2025

**Results For :** TUCKER 2
**Location :** TK2

| | | | |
|---|---|---|---|
| **Lab No. :** | **801670** | **Depth :** | 0 - 6 |
| **ID :** | T-101 | | |
| **Soil Moisture, %** | | | 39.7 |
| **Saturated Soil Paste Analysis (SAR)** | | | |
| **Total Dry Weight, g** | | | |
| | 9 | | |
| **Bulk Density, g/cm** | 3 | | 0.77 |

**Reviewed By :** Nick Ward **7/21/2025** **Copy : 1** **Page 4 of 4**

**Account No. :** 19652

# Soil Analysis Report

WHITE, RYAN
SNAPLANDS LLC
7215 EGYPTIAN DR
FORT COLLINS CO 80525

**Invoice No. :** 1448174
**Date Received :** 06/11/2025
**Date Reported :** 06/13/2025

**Results For :** TUCKER 2
**Location :** TK2

| | | | |
|---|---|---|---|
| **Lab No. :** | **801671** | **Depth :** | 0 - 6 |
| **ID :** | T-102 | | |
| **Soil Moisture, %** | | | 21.7 |
| **Saturated Soil Paste Analysis (SAR)** | | | |
| **Total Dry Weight, g** | | | |
| | | | |
| **Bulk Density, g/cm** | $^3$ | | 1.46 |

**Reviewed By :** Nick Ward **7/21/2025** **Copy : 1** **Page 5 of 4**

## Tucker 2 Control

| | | | | |
|---|---|---|---|---|
| *physical* | Predicted Available Water Capacity | 0.23 | 85 | |
| *physical* | Surface Hardness | | | No Field Readings Submitted |
| *physical* | Subsurface Hardness | | | No Field Readings Submitted |
| *physical* | Aggregate Stability | 42.5 | 74 | |
| *biological* | Organic Matter<br>Soil Organic Carbon: 3.28 / Total Carbon: 3.28 / Total Nitrogen: 0.24 | 5.6 | 100 | |
| *biological* | Predicted Soil Protein | 12.37 | 96 | |
| *biological* | Soil Respiration | 0.7 | 59 | |
| *biological* | Active Carbon | 605 | 71 | |
| *chemical* | Soil pH | 5.3 | 1 | Low pH: Toxicity, Nutrient Availability (note exception for acid loving crop species) |
| *chemical* | Extractable Phosphorus | 1.4 | 41 | |
| *chemical* | Extractable Potassium | 68.9 | 94 | |
| *chemical* | Additional Nutrients<br>Ca: 1645.8 / Mg: 227.2 / S: 7.6<br>Al: 57 / B: 0.16 / Cu: 0.06<br>Fe: 4.1 / Mn: 10.7 / Zn: 2.2 | | 100 | |

# Comprehensive Assessment of Soil Health

From the Cornell Soil Health Laboratory,
Department of Soil and Crop Sciences School of Integrative Plant Science, Cornell University,
Ithaca, NY 14853
https://soilhealthlab.cals.cornell.edu

**Grower:**
7215 Egyptian Dr

Fort Collins, CO 80525

Ryan@snapands.com

**Agricultural Service Provider:**
billing@snaplands.com

Sample ID: QBB1274
Field ID: TK2-T102-D0015-CASH
Date Sampled: 06/06/2025
Crops Grown: SAG / SAG / SAG
Tillage: no till
Coordinates: Latitude: 36.553966

Longitude: -95.935789

Measured Soil Textural Class: **loam**

Sand: **44%** - Silt: **38%** -
Clay: **19%**

| Group | Indicator | Value | Rating | Constraints |
|---|---|---|---|---|

| | |
|---|---|
| Overall Quality Score: | **72** / High |

## Measured Soil Health Indicators

The Cornell Soil Health Test measures several indicators of soil physical, biological and chemical health. These are listed on the left side of the report summary, on the first page. The "value" column shows each result as a value, measured in the laboratory or in the field, in units of measure as described in the indicator summaries below. The "rating" column interprets that measured value on a scale of 0 to 100, where higher scores are better. Ratings in red are particularly important to take note of, but any in yellow, particularly those that are close to a rating of 30 are also important in addressing soil health problems.

- **A rating below 20 indicates *Very Low (constraining)* functioning and is color-coded red.** This indicates a problem that is likely limiting yields, crop quality, and long-term sustainability of the agroecosystem. In several cases this indicates risks of environmental loss as well. The "constraint" column provides a short list of soil processes that are not functioning optimally when an indicator rating is red. It is particularly important to take advantage of any opportunities to improve management that will address these constraints.
- **A rating between 20 and 40 indicates *Low* functioning and is color-coded orange.** This indicates that a soil process is functioning somewhat poorly and addressing this should be considered in the field management plan. The Management Suggestions Table at the end of the Soil Health Assessment Report provides linkages to field management practices that are useful in addressing each soil indicator process.
- **A rating between 40 and 60 indicates *Medium* functioning and is color-coded yellow.** This indicates that soil health could be better, and yield and sustainability could decrease over time if this is not addressed. This is especially so if the condition is being caused, or not being alleviated, by current management. Pay attention particularly to those indicators rated in yellow and close to 40.
- **A rating between 60 and 80 indicates *High* functioning and is color-coded light green.** This indicates that this soil process is functioning at a non-limiting level. Field soil management approaches should be maintained at the current intensity or improved.
- **A rating of 80 or greater indicates *Very High* functioning and is color-coded dark green.** Past management has been effective at maintaining soil health. It can be useful to note which particular aspects of management have likely maintained soil health, so that such management can be continued. Note that soil health is often high, when first converting from a permanent sod or forest. In these situations, intensive management quickly damages soil health when it includes intensive tillage, low organic matter inputs, bare soils for significant parts of the year, or excessive traffic, especially during wet times.
- **The Overall Quality Score** at the bottom of the report is an average of all ratings, and provides an indication of the soil's overall health status. However, the important part is to know which particular soil processes are constrained or suboptimal so that these issues can be addressed through appropriate management. Therefore the ratings for each indicator are more important information.

**The Indicators** measured in the Cornell Soil Health Assessment are important soil properties and characteristics in themselves, but also are representative of key soil processes, necessary for the proper functioning of the soil. The following is a summary of the indicators measured, what each of these indicates about your soil's health status, and what may influence the relevant properties and processes described.

**A Management Suggestions Table** follows, at the end of the report, with short and long term suggestions for addressing constraints or maintaining a well-functioning system. This table will indicate constraints identified in this assessment for your soil sample by the same yellow and red color coding described above. Please also find further useful information by following the links to relevant publications and web resources that follow this section.

**Texture** is an inherent property of soil, meaning that it is rarely changed by management. It is thus not a soil health indicator per se, but is helpful both in interpreting the measured values of indicators (see the Cornell Soil Health Assessment Training Manual), and for deciding on appropriate management strategies that will work for that soil.

**Your soil's measured textural class and composition: loam**

**Sand: 44% - Silt: 38% - Clay: 19%**

**Predicted Available Water Capacity (AWC)** is not a directly measured soil property but is modeled from a suite of measured soil health indicators including the percent sand, silt, clay and organic matter. By using a decision tree approach, the developed Random Forest model can predict the laboratory measured AWC value with no more error than that encountered in the raw laboratory analysis. Details of this modeling effort can be found in our Soil Health Management Series Fact Sheet Number 19-05b.

https://cpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/f/5772/files/2016/12/05b_Soil_Health_Fact_Sheet_Available_Water_Capacity-Predicted-2019-002-132f3th.pdf

The Soil Health Lab continues to offer the laboratory measured AWC test as an add-on to the soil health package analyses.

The Predicted AWC value is presented as grams of water per gram of soil. This value is scored against an observed distribution in regional soils with similar texture. A physical soil characteristic, AWC is an indicator of the amount of plant-available water the soil can store, and therefore how crops will fare in droughty conditions. Soils with lower storage capacity will cause greater risk of drought stress. AWC is generally lower when total organic matter and/or aggregation is low. It can be improved by reducing tillage, long-term cover cropping, and adding large amounts of well-decomposed organic matter such as compost. Coarse textured (sandy) soils inherently store less water than finer textured soils, so that managing for relatively high water storage capacity is particularly important in coarse textured soils. While the textural effect cannot be influenced by management, management decisions can be in part based on an understanding of inherent soil characteristics.

**Your <u>Predicted</u> Available Water Capacity value** is **0.23 g/g**, corresponding with a score of **85**. This score is in the **Very High** range, relative to soils with similar texture. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document.

**Aggregate Stability** is a measure of how well soil aggregates or crumbs hold together under rainfall or other rapid wetting stresses. Measured by the fraction of dried aggregates that disintegrate under a controlled, simulated rainfall event similar in energy delivery to a hard spring rain, the value is presented as a percent, and scored against a distribution observed in regional soils with similar textural characteristics. A physical characteristic of soil, Aggregate Stability is a good indicator of soil biological and physical health. Good aggregate stability helps prevent crusting, runoff, and erosion, and facilitates aeration, infiltration, and water storage, along with improving seed germination and root and microbial health. Aggregate stability is influenced by microbial activity, as aggregates are largely held together by microbial colonies and exudates, and is impacted by management practices, particularly tillage, cover cropping, and fresh organic matter additions.

**Your measured Aggregate Stability value** is **42.5 %**, corresponding with a score of **74**. This score is in the **High** range, relative to soils with similar texture. **This suggests that this soil process is enhancing overall soil resilience. Soil management should aim at maintaining this functionality while addressing any other measured soil constraints as identified in the Soil Health Assessment Report.** Please refer to the management suggestions table at the end of this document.

**Organic Matter** (OM) is a measure of the carbonaceous material in the soil that is biomass or biomass-derived. Measured by the mass lost on combustion of oven-dried soil, the value is presented as a percent of the total soil mass. This is scored against an observed distribution of OM in regional soils with similar texture. A soil characteristic that measures a physical substance of biological origin, OM is a key or central indicator of the physical, biological, and chemical health of the soil. OM content is an important influence on soil aggregate stabilization, water retention, nutrient cycling, and ion exchange capacity. Soils with low organic matter tend to require higher inputs, and be less resilient to drought and extreme rainfall. The retention and accumulation of OM is influenced by management practices such as tillage and cover cropping, as well as by microbial community growth. Intensive tillage and lack of organic matter biomass additions from various sources (amendments, residues, active crop or cover crop growth) will decrease organic matter content and overall soil health with time.

**Total Carbon** (Tot C) is an indicator for the OM in soil, with carbon comprising 48-58% of the total weight of OM. The Tot C analysis measures all of the carbon in a sample using complete oxidation of carbon to CO2 using high temperature combustion (1100C). The measured Tot C includes ***organic*** forms of carbon (Soil Organic Carbon SOC), comprised of available carbon as well as relatively inert carbon in stable organic materials. Carbon can also be found in ***inorganic*** form (Soil Inorganic Carbon SIC) as carbonate minerals such as calcium carbonate (lime).

**Soil Organic Carbon** (SOC) is equivalent to Tot C when there are no carbonate minerals. However, soils above pH 6.5 may contain high levels of carbonates. These carbonates are measured as SIC and subtracted from the Tot C: **SOC = Tot C - SIC**.
**Total Nitrogen** (Tot N) includes the organic (living and non-living) and inorganic (or mineral) forms of nitrogen. About half of the Tot N found in soil is in relatively stable organic compounds. Inorganic nitrogen is liberated from organic nitrogen sources in the soil, particularly proteins and amino acids through the action of soil microorganisms. Ammonium (NH4+) and nitrate (NO3-) are the inorganic forms of nitrogen found in soil that are plant available. The Tot N is determined following the combustion methodology known as DUMAS.

> **Your measured Organic Matter value** is **5.6 %**, corresponding with a score of **100**. This score is in the **Very High** range, relative to soils with similar texture. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document. The **SOC** level is **3.28%**, the **Tot C** level is **3.28%**, the **Tot N** level is **0.24%**.

**Predicted Soil Protein** is not a directly measured soil property but is modeled from a suite of measured soil health indicators including the percent sand, silt, clay and organic matter. By using a decision tree approach, the developed Random Forest model can predict the laboratory measured soil protein value with a tolerable small error. Details of this modeling effort can be found in our Soil Health Management Series Fact Sheet 20-09b. https://cpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/f/5772/files/2020/05/09b-Predicted-Protein.pdf

The Soil Health Lab continues to offer the laboratory measured Soil Protein test as an add-on to the Standard soil health package analyses.

The Predicted Soil Protein is presented as mg per gram of soil. This indicator represents the fraction of the soil organic matter that is present as protein or protein-like substances. Protein content, as organically bound N, influences the ability of the soil to make N available by mineralization, and has been associated with soil aggregation and water movement. Protein content can be influenced by biomass additions, the presence of roots and soil microbes, and tends to decrease with increasing soil disturbance such as tillage.

> **Your measured Predicted Soil Protein value** is **12.37** , corresponding with a score of **96**. This score is in the **Very High** range, relative to soils with similar texture. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document.

**Soil Respiration** is a measure of the metabolic activity of the soil microbial community. Measured by capturing and quantifying carbon dioxide (CO 2) produced by this activity, the value is expressed as total CO 2 released (in mg) per gram of soil over a 4 day incubation period. Respiration is scored against an observed distribution in regional soils, taking texture into account. A direct biological activity measurement, respiration is an

indicator of the biological status of the soil community, integrating abundance and activity of microbial life. Soil biological activity accomplishes numerous important functions, such as cycling of nutrients into and out of soil OM pools, transformations of N between its several forms, and decomposition of incorporated residues. Soil biological activity influences key physical characteristics like OM accumulation, and aggregate formation and stabilization. Microbial activity is influenced by management practices such as tillage, cover cropping, manure or green manure incorporation, and biocide (pesticide, fungicide, herbicide) use.

> **Your measured Soil Respiration value** is **0.7 mg**, corresponding with a score of **59**. This score is in the **Medium** range, relative to soils with similar texture. **This suggests that, while Soil Respiration is functioning at an average level, management practices should be geared toward improving this condition, as it currently indicates suboptimal functioning. Soil management should aim at improving this functionality while addressing any other measured soil constraints as identified in the Soil Health Assessment Report.** Please refer to the management suggestions table at the end of this document.

**Active Carbon** is a measure of the small portion of the organic matter that can serve as an easily available food source for soil microbes, thus helping maintain a healthy soil food web. Measured by potassium permanganate oxidation, the value is presented in parts per million (ppm), and scored against an observed distribution in regional soils with similar texture. While a measure of a class of physical substances, active carbon is a good leading indicator of biological soil health and tends to respond to changes in management earlier than total organic matter content, because when a large population of soil microbes is fed plentifully with enough organic matter over an extended period of time, well-decomposed organic matter builds up. A healthy and diverse microbial community is essential to maintain disease resistance, nutrient cycling, aggregation, and many other important functions. Intensive tillage and lack of organic matter additions from various sources (amendments, residues, active crop or cover crop growth) will decrease active carbon, and thus will over the longer term decrease total organic matter.

> **Your measured Active Carbon value** is **605 ppm**, corresponding with a score of **71**. This score is in the **High** range, relative to soils with similar texture. **This suggests that this soil process is enhancing overall soil resilience. Soil management should aim at maintaining this functionality while addressing any other measured soil constraints as identified in the Soil Health Assessment Report.** Please refer to the management suggestions table at the end of this document.

**Soil pH** is a measure of how acidic the soil is, which controls how available nutrients are to crops. A physico-chemical characteristic of soils, pH is an indicator of the chemical or nutrient status of the soil. Measured with an electrode in a 1:1 soil:water suspension, the value is presented in standard pH units, and scored using an optimality curve. Optimum pH is around 6.2-6.8 for most crops (exceptions include potatoes and blueberries, which grow best in more acidic soil – this is not accounted for in the report interpretation). If pH is too high, nutrients such as phosphorus, iron, manganese, copper and boron become unavailable to the crop. If pH is too low, calcium, magnesium, phosphorus, potassium and

molybdenum become unavailable. Lack of nutrient availability will limit crop yields and quality. Aluminum toxicity can also be a concern in low pH soils, which can severely decrease root growth and yield, and in some cases lead to accumulation of aluminum and other metals in crop tissue. In general, as soil OM increases, crops can tolerate lower soil pH. Soil pH also influences the ability of certain pathogens to thrive, and of beneficial organisms to effectively colonize roots. Raising the pH through lime or wood ash applications, and organic matter additions, will help immobilize aluminum andheavy metals, and maintain proper nutrient availability.

> **Your measured Soil pH value** is **5.3** , corresponding with a score of **1**. This score is in the **Very Low (constraining)** range, relative to soils with similar texture. **Soil pH level should be given a high priority in management decisions based on this assessment, as it is likely to be an important constraint to proper soil functioning and sustainability of management at this time.** Please refer to the management suggestions table at the end of this document.

**Extractable Phosphorus** is a measure of phosphorus (P) availability to a crop. Measured on a modified Morgan's extract using an ICP Spectrometer, the value is presented in parts per million (ppm), and scored against an optimality curve for sufficiency or excess. P is an essential plant macronutrient, and its availability varies with soil pH and mineral composition. Low P values indicate poor P availability to plants, and excessively high P values indicates a risk of adverse environmental impact through runoff and contamination of surface waters. Most soils in the Northeast store unavailable P from the soil's mineral make up or from previously applied fertilizer or manure. This becomes more available to plants as soils warm up. Therefore, incorporating or banding 10-25 lbs/acre of soluble 'starter' P fertilizer at planting can be useful even when soil levels are optimum. Some cover crops, such as buckwheat, are good at mining otherwise unavailable P so that it becomes more available to the following crop. When plants associate with mycorrhizal fungi, these can also help make P (and other nutrients and water) more available to the crop. P is an environmental contaminant and runoff of P into fresh surface water will cause damage through eutrophication, so over-application is strongly discouraged, especially close to surface water, on slopes, and on large scales.

> **Your measured Extractable Phosphorus value** is **1.4 ppm**, corresponding with a score of **41**. This score is in the **Medium** range, relative to soils with similar texture. **This suggests that, while Extractable Phosphorus is functioning at an average level, management practices should be geared toward improving this condition, as it currently indicates suboptimal functioning. Soil management should aim at improving this functionality while addressing any other measured soil constraints as identified in the Soil Health Assessment Report.** Please refer to the management suggestions table at the end of this document.

**Extractable Potassium** is a measure of potassium (K) availability to the crop. Measured on a modified Morgan's extract using an ICP Spectrometer, the value is presented in parts per million (ppm), and scored against an optimality curve for sufficiency. K is an indicator of soil nutrient status, as it is an essential plant macronutrient. Plants with higher

potassium tend to be more tolerant of frost and cold. Thus good potassium levels may help with season extension. While soil pH only marginally affects K availability, K is easily leached from sandy soils and is only weakly held by increased organic matter, so that applications of the amount removed by the specific crop being grown are generally necessary in such soils.

> **Your measured Extractable Potassium value** is **68.9 ppm**, corresponding with a score of **94**. This score is in the **Very High** range, relative to soils with similar texture. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document.

**Additional Nutrients** including (calcium (Ca), magnesium (Mg) and sulfur (S)) with micronutrients (aluminum (Al), boron (B), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn), etc.) are essential plant nutrients taken up by plants in smaller quantities than the macronutrients N, P and K. Note that some leafy vegetables can require significant amounts of these nutrients. If any of these nutrients are deficient, this will decrease yield and crop quality, but toxicities can also occur when concentrations are too high. While Al is not technically a plant nutrient, it can become toxic to crop plants at pH below 5.5. The solubility and availability of all of the elements are strongly influenced by pH and organic matter. High pH favors the availability of magnesium and calcium whereas low pH increases the availability of most micronutrients. High OM and microbial activity tend to increase micronutrient availability. The ratings indicate whether these measured nutrients are deficient or excessive.

> **Your measured Additional Nutrients Rating** is **100**. This score is in the **Very High** range. Magnesium (227.2 ppm) is sufficient, Iron (4.1 ppm) is sufficient, Manganese (10.7 ppm) is sufficient, Zinc (2.2 ppm) is sufficient, Aluminum (57 ppm) is sufficient, Calcium (1645.8 ppm) is sufficient, Copper (0.06 ppm) is sufficient, Sulfur (7.6 ppm) is sufficient, Boron (0.16 ppm) is sufficient. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document.

**Overall Quality Score:** an overall quality score is computed from the individual indicator scores. This score is further rated as follows: less than 20% is regarded as very low, 20-40% is low, 40-60% is medium, 60-80% is high, and greater than 80% is very high. The highest possible quality score is 100 and the least score is 0, thus it is a relative overall soil health status indicator. However, of greater importance than a single overall metric is identification of constrained or suboptimally functioning soil processes, so that these issues can be addressed through appropriate management. The overall soil quality score should be taken as a general summary rather than the main focus.

> **Your Overall Quality Score** is **72**, which is in the **High** range.

## Management Suggestions for Physical and Biological Constraints

| Constraint | Short Term Management Suggestions | Long Term Management Suggestions |
|---|---|---|
| Predicted Available Water Capacity Low | • Add stable organic materials, mulch<br>• Add compost or biochar<br>• Incorporate high biomass cover crop | • Reduce tillage<br>• Rotate with sod crops<br>• Incorporate high biomass cover crop |
| Aggregate Stability Low | • Incorporate fresh organic materials<br>• Use shallow-rooted cover/rotation crops<br>• Add manure, green manure, mulch | • Reduce tillage<br>• Use a surface mulch<br>• Rotate with sod crops and mycorrhizal hosts |
| Organic Matter Low | • Add stable organic materials, mulch<br>• Add compost and biochar<br>• Incorporate high biomass cover crop | • Reduce tillage/mechanical cultivation<br>• Rotate with sod crop<br>• Incorporate high biomass cover crop |
| Predicted Soil Protein Low | • Add N-rich organic matter (low C:N source like manure, high N well-finished compost)<br>• Incorporate young, green, cover crop biomass<br>• Plant legumes and grass-legume mixtures<br>• Inoculate legume seed with Rhizobia & check for nodulation | • Reduce tillage<br>• Rotate with forage legume sod crop<br>• Cover crop and add fresh manure<br>• Keep pH at 6.2-6.5 (helps N fixation)<br>• Monitor C:N ratio of inputs |
| Soil Respiration Low | • Maintain plant cover throughout season<br>• Add fresh organic materials<br>• Add manure, green manure<br>• Consider reducing biocide usage | • Reduce tillage/mechanical cultivation<br>• Increase rotational diversity<br>• Maintain plant cover throughout season<br>• Cover crop with symbiotic host plants |
| Active Carbon Low | • Add fresh organic materials<br>• Use shallow-rooted cover/rotation crops<br>• Add manure, green manure, mulch | • Reduce tillage/mechanical cultivation<br>• Rotate with sod crop<br>• Cover crop whenever possible |

## Management Suggestions for Chemical Constraints

| Constraint | Short Term Management Suggestions | Long Term Management Suggestions |
|---|---|---|
| **Soil pH Low** | • Add lime or wood ash per soil test recommendations<br>• Add calcium sulfate (gypsum) in addition to lime if aluminum is high<br>• Use less ammonium or urea | • Test soil annually & add "maintenance" lime per soil test recommendations to keep pH in range<br>• Raise organic matter to improve buffering capacity |
| Soil pH High | • Stop adding lime or wood ash<br>• Add elemental sulfur per soil test recommendations | • Test soil annually<br>• Use higher % ammonium or urea |
| Extractable Phosphorus Low | • Add P amendments per soil test recommendations<br>• Use cover crops to recycle fixed P<br>• Adjust pH to 6.2-6.5 to free up fixed P | • Promote mycorrhizal populations<br>• Maintain a pH of 6.2-6.5<br>• Use cover crops to recycle fixed P |
| Extractable Phosphorus High | • Stop adding manure and compost<br>• Choose low or no-P fertilizer blend<br>• Apply only 20 lbs/ac starter P if needed<br>• Apply P at or below crop removal rates | • Use cover crops that accumulate P and export to low P fields or offsite<br>• Consider low P rations for livestock<br>• Consider phytase for non-ruminants |
| Extractable Potassium Low | • Add wood ash, fertilizer, manure, or compost per soil test recommendations<br>• Use cover crops to recycle K<br>• Choose a high K fertilizer blend | • Use cover crops to recycle K<br>• Add "maintenance" K per soil recommendations each year to keep K consistently available |
| Additional Nutrients Low | • Add chelated micronutrients per soil test recommendations<br>• Use cover crops to recycle micronutrients<br>• Do not exceed pH 6.5 for most crops | • Promote mycorrhizal populations<br>• Improve organic matter<br>• Decrease soil P (binds micronutrients)<br>• Add lime (Ca and Mg), gypsum (S), rock powder |
| Additional Nutrients High | • Raise pH to 6.2-6.5 (for all high micro-nutrients and Aluminum)<br>• Do not use fertilizers with micronutrients | • Maintain a pH of 6.2-6.5<br>• Monitor irrigation/improve drainage<br>• Avoid compost additions with high micronutrient levels |

School of Integrative Plant Science, Soil and Crop Sciences Section, 804 Bradfield Hall, 306 Tower Road, Cornell University, Ithaca, NY 14853, email: soilhealth@cornell.edu

College of Agriculture and Life Sciences, Cornell University

Developed in partnership with Cornell Soil Health, Farmier, and GreenStart.
Powered by farmOS.

# Comprehensive Assessment of Soil Health

From the Cornell Soil Health Laboratory, Department of Soil and Crop Sciences School of Integrative Plant Science, Cornell University, Ithaca, NY 14

**Grower:**

7215 Egyptian Dr

Fort Collins, CO 80525

Ryan@snapands.com

**Agricultural Service Provider:**

billing@snaplands.com

Sample ID:

Field ID:

Date Sampled:

Crops Grown:

Tillage:

Coordinates:

Measured Soil Textural Class: **silty clay loam**

Sand: **18%** - Silt: **48%** - Clay: **33%**

| Group | Indicator | | | |
|---|---|---|---|---|
| *physical* | Predicted Available Water Capacity | **0.25** | **93** | |
| *physical* | Surface Hardness | | | No Field Readings Submitted |
| *physical* | Subsurface Hardness | | | No Field Readings Submitted |
| *physical* | Aggregate Stability | **29.2** | **38** | |
| *biological* | Organic Matter<br>Soil Organic Carbon: 4.87 / Total Carbon: 4.87 / Total Nitrogen: 0.34 | **7.9** | **100** | |
| *biological* | Predicted Soil Protein | **9.07** | **85** | |
| *biological* | Soil Respiration | **0.8** | **79** | |
| *biological* | Active Carbon | **964** | **97** | |
| *chemical* | Soil pH | **6.2** | **98** | |
| *chemical* | Extractable Phosphorus | **2.1** | **61** | |
| *chemical* | Extractable Potassium | **170.3** | **100** | |
| *chemical* | Additional Nutrients<br>Ca: 2906 / Mg: 501.8 / S: 5.7<br>Al: 12.8 / B: 0.35 / Cu: 0.08<br>Fe: 1.7 / Mn: 5.2 / Zn: 1.5 | | **100** | |

Overall Quality Score: **85** / Very High

## Measured Soil Health Indicators

The Cornell Soil Health Test measures several indicators of soil physical, biological and chemical health. These are listed on the left side of the report summary, on the first page. The "value" column shows each result as a value, measured in the laboratory or in the field, in units of measure as described in the indicator summaries below. The "rating" column interprets that measured value on a scale of 0 to 100, where higher scores are better. Ratings in red are particularly important to take note of, but any in yellow, particularly those that are close to a rating of 30 are also important in addressing soil health problems.

- **A rating below 20 indicates *Very Low (constraining)* functioning and is color-coded red.** This indicates a problem that is likely limiting yields, crop quality, and long-term sustainability of the agroecosystem. In several cases this indicates risks of environmental loss as well. The "constraint" column provides a short list of soil processes that are not functioning optimally when an indicator rating is red. It is particularly important to take advantage of any opportunities to improve management that will address these constraints.
- **A rating between 20 and 40 indicates *Low* functioning and is color-coded orange.** This indicates that a soil process is functioning somewhat poorly and addressing this should be considered in the field management plan. The Management Suggestions Table at the end of the Soil Health Assessment Report provides linkages to field management practices that are useful in addressing each soil indicator process.
- **A rating between 40 and 60 indicates *Medium* functioning and is color-coded yellow.** This indicates that soil health could be better, and yield and sustainability could decrease over time if this is not addressed. This is especially so if the condition is being caused, or not being alleviated, by current management. Pay attention particularly to those indicators rated in yellow and close to 40.
- **A rating between 60 and 80 indicates *High* functioning and is color-coded light green.** This indicates that this soil process is functioning at a non-limiting level. Field soil management approaches should be maintained at the current intensity or improved.
- **A rating of 80 or greater indicates *Very High* functioning and is color-coded dark green.** Past management has been effective at maintaining soil health. It can be useful to note which particular aspects of management have likely maintained soil health, so that such management can be continued. Note that soil health is often high, when first converting from a permanent sod or forest. In these situations, intensive management quickly damages soil health when it includes intensive tillage, low organic matter inputs, bare soils for significant parts of the year, or excessive traffic, especially during wet times.
- **The Overall Quality Score** at the bottom of the report is an average of all ratings, and provides an indication of the soil's overall health status. However, the important part is to know which particular soil processes are constrained or suboptimal so that these issues can be addressed through appropriate management. Therefore the ratings for each indicator are more important information.

**The Indicators** measured in the Cornell Soil Health Assessment are important soil properties and characteristics in themselves, but also are representative of key soil processes, necessary for the proper functioning of the soil. The following is a summary of the indicators measured, what each of these indicates about your soil's health status, and what may influence the relevant properties and processes described.

**A Management Suggestions Table** follows, at the end of the report, with short and long term suggestions for addressing constraints or maintaining a well-functioning system. This table will indicate constraints identified in this assessment for your soil sample by the same yellow and red color coding described above. Please also find further useful information by following the links to relevant publications and web resources that follow this section.

**Texture** is an inherent property of soil, meaning that it is rarely changed by management. It is thus not a soil health indicator per se, but is helpful both in interpreting the measured values of indicators (see the Cornell Soil Health Assessment Training Manual), and for deciding on appropriate management strategies that will work for that soil.

**Your soil's measured textural class and composition: silty clay loam**

**Sand: 18% - Silt: 48% - Clay: 33%**

**Predicted Available Water Capacity (AWC)** is not a directly measured soil property but is modeled from a suite of measured soil health indicators including the percent sand, silt, clay and organic matter. By using a decision tree approach, the developed Random Forest model can predict the laboratory measured AWC value with no more error than that encountered in the raw laboratory analysis. Details of this modeling effort can be found in our Soil Health Management Series Fact Sheet Number 19-05b.

https://cpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/f/5772/files/2016/12/05b_Soil_Health_Fact_Sheet_Available_Water_Capacity-Predicted-2019-002-132f3th.pdf

The Soil Health Lab continues to offer the laboratory measured AWC test as an add-on to the soil health package analyses.

The Predicted AWC value is presented as grams of water per gram of soil. This value is scored against an observed distribution in regional soils with similar texture. A physical soil characteristic, AWC is an indicator of the amount of plant-available water the soil can store, and therefore how crops will fare in droughty conditions. Soils with lower storage capacity will cause greater risk of drought stress. AWC is generally lower when total organic matter and/or aggregation is low. It can be improved by reducing tillage, long-term cover cropping, and adding large amounts of well-decomposed organic matter such as compost. Coarse textured (sandy) soils inherently store less water than finer textured soils, so that managing for relatively high water storage capacity is particularly important in coarse textured soils. While the textural effect cannot be influenced by management, management decisions can be in part based on an understanding of inherent soil characteristics.

**Your <u>Predicted</u> Available Water Capacity value** is **0.25 g/g**, corresponding with a score of **93**. This score is in the **Very High** range, relative to soils with similar texture. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document.

**Aggregate Stability** is a measure of how well soil aggregates or crumbs hold together under rainfall or other rapid wetting stresses. Measured by the fraction of dried aggregates that disintegrate under a controlled, simulated rainfall event similar in energy delivery to a hard spring rain, the value is presented as a percent, and scored against a distribution observed in regional soils with similar textural characteristics. A physical characteristic of soil, Aggregate Stability is a good indicator of soil biological and physical health. Good aggregate stability helps prevent crusting, runoff, and erosion, and facilitates aeration, infiltration, and water storage, along with improving seed germination and root and microbial health. Aggregate stability is influenced by microbial activity, as aggregates are largely held together by microbial colonies and exudates, and is impacted by management practices, particularly tillage, cover cropping, and fresh organic matter additions.

**Your measured Aggregate Stability value** is **29.2 %**, corresponding with a score of **38**. This score is in the **Low** range, relative to soils with similar texture. **This suggests that, while Aggregate Stability does not currently register as a strong constraint, management practices should be geared toward improving this condition, as it currently indicates suboptimal functioning.** Please refer to the management suggestions table at the end of this document.

**Organic Matter** (OM) is a measure of the carbonaceous material in the soil that is biomass or biomass-derived. Measured by the mass lost on combustion of oven-dried soil, the value is presented as a percent of the total soil mass. This is scored against an observed distribution of OM in regional soils with similar texture. A soil characteristic that measures a physical substance of biological origin, OM is a key or central indicator of the physical, biological, and chemical health of the soil. OM content is an important influence on soil aggregate stabilization, water retention, nutrient cycling, and ion exchange capacity. Soils with low organic matter tend to require higher inputs, and be less resilient to drought and extreme rainfall. The retention and accumulation of OM is influenced by management practices such as tillage and cover cropping, as well as by microbial community growth. Intensive tillage and lack of organic matter biomass additions from various sources (amendments, residues, active crop or cover crop growth) will decrease organic matter content and overall soil health with time.

**Total Carbon** (Tot C) is an indicator for the OM in soil, with carbon comprising 48-58% of the total weight of OM. The Tot C analysis measures all of the carbon in a sample using complete oxidation of carbon to CO2 using high temperature combustion (1100C). The measured Tot C includes ***organic*** forms of carbon (Soil Organic Carbon SOC), comprised of available carbon as well as relatively inert carbon in stable organic materials. Carbon can also be found in ***inorganic*** form (Soil Inorganic Carbon SIC) as carbonate minerals such as calcium carbonate (lime).

**Soil Organic Carbon** (SOC) is equivalent to Tot C when there are no carbonate minerals. However, soils above pH 6.5 may contain high levels of carbonates. These carbonates are measured as SIC and subtracted from the Tot C: **SOC = Tot C - SIC**.
**Total Nitrogen** (Tot N) includes the organic (living and non-living) and inorganic (or mineral) forms of nitrogen. About half of the Tot N found in soil is in relatively stable organic compounds. Inorganic nitrogen is liberated from organic nitrogen sources in the soil, particularly proteins and amino acids through the action of soil microorganisms. Ammonium (NH4+) and nitrate (NO3-) are the inorganic forms of nitrogen found in soil that are plant available. The Tot N is determined following the combustion methodology known as DUMAS.

> **Your measured Organic Matter value** is **7.9 %**, corresponding with a score of **100**. This score is in the **Very High** range, relative to soils with similar texture. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document. The **SOC** level is **4.87%**, the **Tot C** level is **4.87%**, the **Tot N** level is **0.34%**.

**Predicted Soil Protein** is not a directly measured soil property but is modeled from a suite of measured soil health indicators including the percent sand, silt, clay and organic matter. By using a decision tree approach, the developed Random Forest model can predict the laboratory measured soil protein value with a tolerable small error. Details of this modeling effort can be found in our Soil Health Management Series Fact Sheet 20-09b. https://cpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/f/5772/files/2020/05/09b-Predicted-Protein.pdf

The Soil Health Lab continues to offer the laboratory measured Soil Protein test as an add-on to the Standard soil health package analyses.

The Predicted Soil Protein is presented as mg per gram of soil. This indicator represents the fraction of the soil organic matter that is present as protein or protein-like substances. Protein content, as organically bound N, influences the ability of the soil to make N available by mineralization, and has been associated with soil aggregation and water movement. Protein content can be influenced by biomass additions, the presence of roots and soil microbes, and tends to decrease with increasing soil disturbance such as tillage.

> **Your measured Predicted Soil Protein value** is **9.07** , corresponding with a score of **85**. This score is in the **Very High** range, relative to soils with similar texture. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document.

**Soil Respiration** is a measure of the metabolic activity of the soil microbial community. Measured by capturing and quantifying carbon dioxide (CO 2) produced by this activity, the value is expressed as total CO 2 released (in mg) per gram of soil over a 4 day incubation period. Respiration is scored against an observed distribution in regional soils, taking texture into account. A direct biological activity measurement, respiration is an

indicator of the biological status of the soil community, integrating abundance and activity of microbial life. Soil biological activity accomplishes numerous important functions, such as cycling of nutrients into and out of soil OM pools, transformations of N between its several forms, and decomposition of incorporated residues. Soil biological activity influences key physical characteristics like OM accumulation, and aggregate formation and stabilization. Microbial activity is influenced by management practices such as tillage, cover cropping, manure or green manure incorporation, and biocide (pesticide, fungicide, herbicide) use.

> **Your measured Soil Respiration value** is **0.8 mg**, corresponding with a score of **79**. This score is in the **High** range, relative to soils with similar texture. **This suggests that this soil process is enhancing overall soil resilience. Soil management should aim at maintaining this functionality while addressing any other measured soil constraints as identified in the Soil Health Assessment Report.** Please refer to the management suggestions table at the end of this document.

**Active Carbon** is a measure of the small portion of the organic matter that can serve as an easily available food source for soil microbes, thus helping maintain a healthy soil food web. Measured by potassium permanganate oxidation, the value is presented in parts per million (ppm), and scored against an observed distribution in regional soils with similar texture. While a measure of a class of physical substances, active carbon is a good leading indicator of biological soil health and tends to respond to changes in management earlier than total organic matter content, because when a large population of soil microbes is fed plentifully with enough organic matter over an extended period of time, well-decomposed organic matter builds up. A healthy and diverse microbial community is essential to maintain disease resistance, nutrient cycling, aggregation, and many other important functions. Intensive tillage and lack of organic matter additions from various sources (amendments, residues, active crop or cover crop growth) will decrease active carbon, and thus will over the longer term decrease total organic matter.

> **Your measured Active Carbon value** is **964 ppm**, corresponding with a score of **97**. This score is in the **Very High** range, relative to soils with similar texture. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document.

**Soil pH** is a measure of how acidic the soil is, which controls how available nutrients are to crops. A physico-chemical characteristic of soils, pH is an indicator of the chemical or nutrient status of the soil. Measured with an electrode in a 1:1 soil:water suspension, the value is presented in standard pH units, and scored using an optimality curve. Optimum pH is around 6.2-6.8 for most crops (exceptions include potatoes and blueberries, which grow best in more acidic soil – this is not accounted for in the report interpretation). If pH is too high, nutrients such as phosphorus, iron, manganese, copper and boron become unavailable to the crop. If pH is too low, calcium, magnesium, phosphorus, potassium and molybdenum become unavailable. Lack of nutrient availability will limit crop yields and quality. Aluminum toxicity can also be a concern in low pH soils, which can severely decrease root growth and yield, and in some cases lead to accumulation of aluminum and

other metals in crop tissue. In general, as soil OM increases, crops can tolerate lower soil pH. Soil pH also influences the ability of certain pathogens to thrive, and of beneficial organisms to effectively colonize roots. Raising the pH through lime or wood ash applications, and organic matter additions, will help immobilize aluminum andheavy metals, and maintain proper nutrient availability.

> **Your measured Soil pH value** is **6.2** , corresponding with a score of **98**. This score is in the **Very High** range, relative to soils with similar texture. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document.

**Extractable Phosphorus** is a measure of phosphorus (P) availability to a crop. Measured on a modified Morgan's extract using an ICP Spectrometer, the value is presented in parts per million (ppm), and scored against an optimality curve for sufficiency or excess. P is an essential plant macronutrient, and its availability varies with soil pH and mineral composition. Low P values indicate poor P availability to plants, and excessively high P values indicates a risk of adverse environmental impact through runoff and contamination of surface waters. Most soils in the Northeast store unavailable P from the soil's mineral make up or from previously applied fertilizer or manure. This becomes more available to plants as soils warm up. Therefore, incorporating or banding 10-25 lbs/acre of soluble 'starter' P fertilizer at planting can be useful even when soil levels are optimum. Some cover crops, such as buckwheat, are good at mining otherwise unavailable P so that it becomes more available to the following crop. When plants associate with mycorrhizal fungi, these can also help make P (and other nutrients and water) more available to the crop. P is an environmental contaminant and runoff of P into fresh surface water will cause damage through eutrophication, so over-application is strongly discouraged, especially close to surface water, on slopes, and on large scales.

> **Your measured Extractable Phosphorus value** is **2.1 ppm**, corresponding with a score of **61**. This score is in the **High** range, relative to soils with similar texture. **This suggests that this soil process is enhancing overall soil resilience. Soil management should aim at maintaining this functionality while addressing any other measured soil constraints as identified in the Soil Health Assessment Report.** Please refer to the management suggestions table at the end of this document.

**Extractable Potassium** is a measure of potassium (K) availability to the crop. Measured on a modified Morgan's extract using an ICP Spectrometer, the value is presented in parts per million (ppm), and scored against an optimality curve for sufficiency. K is an indicator of soil nutrient status, as it is an essential plant macronutrient. Plants with higher potassium tend to be more tolerant of frost and cold. Thus good potassium levels may help with season extension. While soil pH only marginally affects K availability, K is easily leached from sandy soils and is only weakly held by increased organic matter, so that applications of the amount removed by the specific crop being grown are generally necessary in such soils.

**Your measured Extractable Potassium value** is **170.3 ppm**, corresponding with a score of **100**. This score is in the **Very High** range, relative to soils with similar texture. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document.

**Additional Nutrients** including (calcium (Ca), magnesium (Mg) and sulfur (S)) with micronutrients (aluminum (Al), boron (B), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn), etc.) are essential plant nutrients taken up by plants in smaller quantities than the macronutrients N, P and K. Note that some leafy vegetables can require significant amounts of these nutrients. If any of these nutrients are deficient, this will decrease yield and crop quality, but toxicities can also occur when concentrations are too high. While Al is not technically a plant nutrient, it can become toxic to crop plants at pH below 5.5. The solubility and availability of all of the elements are strongly influenced by pH and organic matter. High pH favors the availability of magnesium and calcium whereas low pH increases the availability of most micronutrients. High OM and microbial activity tend to increase micronutrient availability. The ratings indicate whether these measured nutrients are deficient or excessive.

**Your measured Additional Nutrients Rating** is **100**. This score is in the **Very High** range. Magnesium (501.8 ppm) is sufficient, Iron (1.7 ppm) is sufficient, Manganese (5.2 ppm) is sufficient, Zinc (1.5 ppm) is sufficient, Aluminum (12.8 ppm) is sufficient, Calcium (2906 ppm) is sufficient, Copper (0.08 ppm) is sufficient, Sulfur (5.7 ppm) is sufficient, Boron (0.35 ppm) is sufficient. **This suggests that management practices should be geared toward maintaining this condition, as it currently indicates ideal soil functioning.** Please refer to the management suggestions table at the end of this document.

**Overall Quality Score:** an overall quality score is computed from the individual indicator scores. This score is further rated as follows: less than 20% is regarded as very low, 20-40% is low, 40-60% is medium, 60-80% is high, and greater than 80% is very high. The highest possible quality score is 100 and the least score is 0, thus it is a relative overall soil health status indicator. However, of greater importance than a single overall metric is identification of constrained or suboptimally functioning soil processes, so that these issues can be addressed through appropriate management. The overall soil quality score should be taken as a general summary rather than the main focus.

**Your Overall Quality Score** is **85**, which is in the **Very High** range.

## Management Suggestions for Physical and Biological Constraints

| Constraint | Short Term Management Suggestions | Long Term Management Suggestions |
|---|---|---|
| Predicted Available Water Capacity Low | • Add stable organic materials, mulch<br>• Add compost or biochar<br>• Incorporate high biomass cover crop | • Reduce tillage<br>• Rotate with sod crops<br>• Incorporate high biomass cover crop |
| Aggregate Stability Low | • Incorporate fresh organic materials<br>• Use shallow-rooted cover/rotation crops<br>• Add manure, green manure, mulch | • Reduce tillage<br>• Use a surface mulch<br>• Rotate with sod crops and mycorrhizal hosts |
| Organic Matter Low | • Add stable organic materials, mulch<br>• Add compost and biochar<br>• Incorporate high biomass cover crop | • Reduce tillage/mechanical cultivation<br>• Rotate with sod crop<br>• Incorporate high biomass cover crop |
| Predicted Soil Protein Low | • Add N-rich organic matter (low C:N source like manure, high N well-finished compost)<br>• Incorporate young, green, cover crop biomass<br>• Plant legumes and grass-legume mixtures<br>• Inoculate legume seed with Rhizobia & check for nodulation | • Reduce tillage<br>• Rotate with forage legume sod crop<br>• Cover crop and add fresh manure<br>• Keep pH at 6.2-6.5 (helps N fixation)<br>• Monitor C:N ratio of inputs |
| Soil Respiration Low | • Maintain plant cover throughout season<br>• Add fresh organic materials<br>• Add manure, green manure<br>• Consider reducing biocide usage | • Reduce tillage/mechanical cultivation<br>• Increase rotational diversity<br>• Maintain plant cover throughout season<br>• Cover crop with symbiotic host plants |
| Active Carbon Low | • Add fresh organic materials<br>• Use shallow-rooted cover/rotation crops<br>• Add manure, green manure, mulch | • Reduce tillage/mechanical cultivation<br>• Rotate with sod crop<br>• Cover crop whenever possible |

## Management Suggestions for Chemical Constraints

| Constraint | Short Term Management Suggestions | Long Term Management Suggestions |
|---|---|---|
| Soil pH Low | • Add lime or wood ash per soil test recommendations<br>• Add calcium sulfate (gypsum) in addition to lime if aluminum is high<br>• Use less ammonium or urea | • Test soil annually & add "maintenance" lime per soil test recommendations to keep pH in range<br>• Raise organic matter to improve buffering capacity |
| Soil pH High | • Stop adding lime or wood ash<br>• Add elemental sulfur per soil test recommendations | • Test soil annually<br>• Use higher % ammonium or urea |
| Extractable Phosphorus Low | • Add P amendments per soil test recommendations<br>• Use cover crops to recycle fixed P<br>• Adjust pH to 6.2-6.5 to free up fixed P | • Promote mycorrhizal populations<br>• Maintain a pH of 6.2-6.5<br>• Use cover crops to recycle fixed P |
| Extractable Phosphorus High | • Stop adding manure and compost<br>• Choose low or no-P fertilizer blend<br>• Apply only 20 lbs/ac starter P if needed<br>• Apply P at or below crop removal rates | • Use cover crops that accumulate P and export to low P fields or offsite<br>• Consider low P rations for livestock<br>• Consider phytase for non-ruminants |
| Extractable Potassium Low | • Add wood ash, fertilizer, manure, or compost per soil test recommendations<br>• Use cover crops to recycle K<br>• Choose a high K fertilizer blend | • Use cover crops to recycle K<br>• Add "maintenance" K per soil recommendations each year to keep K consistently available |
| Additional Nutrients Low | • Add chelated micronutrients per soil test recommendations<br>• Use cover crops to recycle micronutrients<br>• Do not exceed pH 6.5 for most crops | • Promote mycorrhizal populations<br>• Improve organic matter<br>• Decrease soil P (binds micronutrients)<br>• Add lime (Ca and Mg), gypsum (S), rock powder |
| Additional Nutrients High | • Raise pH to 6.2-6.5 (for all high micro-nutrients and Aluminum)<br>• Do not use fertilizers with micronutrients | • Maintain a pH of 6.2-6.5<br>• Monitor irrigation/improve drainage<br>• Avoid compost additions with high micronutrient levels |

School of Integrative Plant Science, Soil and Crop Sciences Section, 804 Bradfield Hall, 306 Tower Road, Cornell University, Ithaca, NY 14853, email: soilhealth@cornell.edu

College of Agriculture and Life Sciences, Cornell University

Developed in partnership with Cornell Soil Health, Farmier, and GreenStart.
Powered by farmOS.

TEXAS A&M AGRILIFE EXTENSION

# Forage Analysis Report

Soil, Water and Forage Testing Laboratory
Department of Soil and Crop Sciences
2478 TAMU
College Station, TX 77843-2478
979-845-4816 (phone)
979-845-5958 (FAX)
Visit our website: http://soiltesting.tamu.edu

Sample received on: 6/12/2025
Printed on: 6/18/2025

Report generated for:

**Ryan White**
**Snaplands, LLC**
**7215 Egyptian Dr**

**FORT COLLINS, CO 80525**
**Osage, CO County**

| Laboratory number / Customer Sample ID / Forage Type / Forage Use | | 65167710 Packard Plugsite Other WSG Hay | 65167711 Scudder AG20 Control Other WSG Hay | 65167712 Scudder AG20 Treatment Other WSG Hay | 65167713 Tucker Treatment Other WSG Hay |
|---|---|---|---|---|---|
| **Crude Protein** | % | 8.1 | 10.7 | 9.6 | 6.9 |
| **Acid Detergent Fiber** | % | 30.8 | 29.9 | 33.5 | 55.1 |
| **TDN-based on ADF** | % | 60.6 | 62.2 | 59.0 | 41.4 |
| **Net Energy Lactation** | Mcal/lb | 0.62 | 0.64 | 0.60 | 0.41 |
| **Mineral Analysis** | | | | | |
| **Phosphorus** | % | 0.16 | 0.18 | 0.20 | 0.08 |
| **Potassium** | % | 1.91 | 1.61 | 1.51 | 1.30 |
| **Calcium** | % | 1.20 | 0.34 | 0.44 | 0.44 |
| **Magnesium** | % | 0.19 | 0.13 | 0.15 | 0.13 |
| **Sodium** | ppm | 2. | 1. | 2. | 1. |
| **Zinc** | ppm | 41. | 28. | 24. | 32. |
| **Iron** | ppm | 64. | 81. | 48. | 84. |
| **Copper** | ppm | 0. | 1. | 0. | 0. |
| **Manganese** | ppm | 40. | 39. | 36. | 102. |
| **Sulfur** | ppm | 1653. | 1005. | 893. | 834. |
| **Boron** | ppm | 16.50 | 0.07 | 0.08 | 0.07 |

Results reported on a 100% dry matter basis.

For more information visit: forages.tamu.ed
soiltesting.tamu.ed
forage.tamu.ed

# Forage Analysis Report

Soil, Water and Forage Testing Laboratory
Department of Soil and Crop Sciences
2478 TAMU
College Station, TX 77843-2478
979-845-4816 (phone)
979-845-5958 (FAX)
Visit our website: http://soiltesting.tamu.edu

Sample received on: 6/12/2025
Printed on: 6/18/2025

Report generated for:
**Ryan White**
**Snaplands, LLC**
**7215 Egyptian Dr**

**FORT COLLINS, CO 80525**
**Osage, CO County**

| boratory number<br>Customer Sample ID<br><br>Forage Type<br>Forage Use | | 65167710<br>Packard Plugsite<br><br>Other WSG<br>Hay | 65167711<br>Scudder AG20 Control<br><br>Other WSG<br>Hay | 65167712<br>Scudder AG20 Treatment<br><br>Other WSG<br>Hay | 65167713<br>Tucker Treatment<br><br>Other WSG<br>Hay |
|---|---|---|---|---|---|
| **Crude Protein** | % | 8.1 | 10.7 | 9.6 | 6.9 |
| **Acid Detergent Fiber** | % | 30.8 | 29.9 | 33.5 | 55.1 |
| **TDN-based on ADF** | % | 60.6 | 62.2 | 59.0 | 41.4 |
| **Net Energy Lactation** | Mcal/lb | 0.62 | 0.64 | 0.60 | 0.41 |
| **Mineral Analysis** | | | | | |
| **Phosphorus** | % | 0.16 | 0.18 | 0.20 | 0.08 |
| **Potassium** | % | 1.91 | 1.61 | 1.51 | 1.30 |
| **Calcium** | % | 1.20 | 0.34 | 0.44 | 0.44 |
| **Magnesium** | % | 0.19 | 0.13 | 0.15 | 0.13 |
| **Sodium** | ppm | 2. | 1. | 2. | 1. |
| **Zinc** | ppm | 41. | 28. | 24. | 32. |
| **Iron** | ppm | 64. | 81. | 48. | 84. |
| **Copper** | ppm | 0. | 1. | 0. | 0. |
| **Manganese** | ppm | 40. | 39. | 36. | 102. |
| **Sulfur** | ppm | 1653. | 1005. | 893. | 834. |
| **Boron** | ppm | 16.50 | 0.07 | 0.08 | 0.07 |

Results reported on a 100% dry matter basis.
For more information visit: forages.tamu.ed
soiltesting.tamu.ed
forage.tamu.ed

TEXAS A&M AGRILIFE EXTENSION

# Forage NIR Analysis Report

Soil, Water and Forage Testing Laboratory
Department of Soil and Crop Sciences
2478 TAMU
College Station, TX 77843-2478
979-845-4816 (phone)
979-845-5958 (FAX)
Visit our website: http://soiltesting.tamu.edu

Sample received on: 6/12/2025
Printed on: 6/18/2025

Report generated for:
**Ryan White**
**Snaplands, LLC**
**7215 Egyptian Dr**

**FORT COLLINS, CO 80525**
**Osage, CO County**

| y number Customer Sample ID<br>Forage Type<br>Forage Use | | 65167710<br>Packard Plugsite<br>Other WSG<br>Hay | 65167711<br>Scudder AG20 Control<br>Other WSG<br>Hay | 65167712<br>Scudder AG20 Treatment<br>Other WSG<br>Hay | 65167713<br>Tucker Treatment<br>Other WSG<br>Hay |
|---|---|---|---|---|---|
| **Crude Protein** | % | 10.3 | 12.3 | 11.2 | 10.0 |
| **Dig. Crude Protein** | % | 6.1 | 7.9 | 6.9 | 5.8 |
| **Acid Detergent Fiber** | % | 32.1 | 31.8 | 33.5 | 36.3 |
| **Neutral Detergent Fiber** | % | 44.7 | 54.3 | 52.2 | 53.7 |
| **TDN-based on ADF** | % | 60.4 | 61.3 | 59.6 | 57.0 |
| **Net Energy Lactation** | Mcal/lb | 0.62 | 0.63 | 0.61 | 0.58 |
| **Net Energy Maintance** | Mcal/lb | 0.66 | 0.68 | 0.65 | 0.62 |
| **Net Energy Gain** | Mcal/lb | 0.34 | 0.35 | 0.33 | 0.29 |
| **Energy Est.** | therms/cwt | 51.0 | 51.9 | 50.3 | 47.9 |
| **IVTD(in vitro true digestib** | % | 79.1 | 73.6 | 72.9 | 67.0 |
| **Ash** | % | 6.7 | 5.6 | 6.0 | 6.9 |
| **Relative Feed Value(RFV)** | | 133.1 | 109.8 | 111.9 | 104.9 |
| **NIR Mineral Analysis** | | | | | |
| **Phosphorus** | % | 0.26 | 0.24 | 0.24 | 0.22 |
| **Potassium** | % | 1.29 | 1.26 | 1.13 | 1.02 |
| **Calcium** | % | 0.45 | 0.39 | 0.33 | 0.34 |
| **Magnesium** | % | 0.17 | 0.15 | 0.14 | 0.16 |
| | | | 1.42 | 1.55 | 1.44 |
| | | | 27.9 | 24.4 | 31.9 |
| | | | 80.9 | 48.3 | 84.1 |
| | | | 1.0 | 0.4 | 0.3 |

**NIR mineral data should be used for comparison purposes only. Wet chemistry analysis should be used if balancing rations.**

Results reported on a 100% dry matter basis

For more information visit: http://soiltesting.tamu.edu - the laboratory website
http://forage.tamu.edu - Forageval program for estimating rate of gain for beef cattl

# SnapLands™ LLC Background & Methodology

## Overview

SnapLands™ LLC is a global leader on millions of acres of regenerating lands with profitable and verifiable outcomes. Founded in 2017 on a working Montana ranch, SnapLands™ quickly adopted and advanced the Land EKG business, which was established in 1994. Today, their verified land health services and programs have served 17 counties and oversee land health data on over 8 million acres. SnapLands™ strategies respect each client's local needs, co-creating solutions from first-hand international management experience in large-scale agricultural and sustainable operations using leading research and technology.

## Services and Impact

SnapLands™ clients manage millions of private and public acres, restoring wild lands and ecosystem services. Their services provide local insights and strategies tailored to each client's key performance indicators, such as food production, profitability, carbon sequestration, ecosystem services, science-based market differentiation, and verifiable sustainable impacts. This approach empowers teams with cross-cutting data utilized by investors, fund managers, landowners, business executives, educational organizations, academics, market partners, management teams, and policymakers. Since their founding, the SnapLands™ team has been committed to helping future leaders create a sustainable environment worth living in.

## The Regenerative Methodology Scaling Impact and Application

Since 1994, SnapLands™ Land EKG methods have been used in rangelands from Florida to southern Canada to Arizona. Practitioners and endorsees of SnapLands™ Land EKG methods include the US Forest Service, Bureau of Land Management, ARS, Native American Tribes, Regenerative Land Management Leaders, The National Cattlemen's Association, Food Brands, Rodale Institute, Natural Resources Conservation Service, The Savory Institute, Grasslands LLC, Quivira Coalition, and active working land managers.

SnapLands™ grows teams by maximizing the production, culture, and land ethic of their operations. They provide and interpret facts gathered directly from working landscapes for individuals working the land. These facts are used to generate near and long-term outcomes to capitalize on landscape-scale health.

## Ecological Monitoring and Reporting

SnapLands™ employs the most effective land health monitoring methods to communicate efficient business opportunities and short- and long-term trends. These monitoring methods, selected through years of ranch management and coupled with firsthand experience in academic

study, vetted rangeland research, landscape-scale ecosystem accounting, and collaboration with multiple academic institutions, land managers, range consultants, government agencies, and non-profits, provide an on-the-ground understanding of rangelands and rangeland management today. These methods are applicable in grassland to open forest ecosystems from 50 to 1,250 feet in elevation.

SnapLands™ offers customizable field and online reports that can be immediately accessed and shared through a secure account login. These professional reports include tables (such as production and ecological function, and stocking rates), time-lapse imagery, graphs, and field notes. The monitoring results may also be used in the accuracy assessments of certain remote sensing applications.

## Certified Training and Verification

SnapLands™ verifies properties' land health through training and certifying land health monitoring technicians, and provides verified data to food, leather, and fiber certifications and natural resource assets and impact accounting. They also train and consult with international companies and organizations in turnkey regenerative land management and impact accounting.