

Perpetually Sustainable Grazingland Ecosystems

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Grassland ecosystems are open systems with biological, chemical, and atmospheric pathways that transfer essential elements into, inputs (gains), and out of, outputs (losses), the ecosystem. Grazingland ecosystems that have greater output than input of essential elements are deteriorating and not sustainable. Ecosystems that have greater natural input than output of essential elements are healthy and sustainable (Manske 2012).

The major essential elements of carbon, hydrogen, nitrogen, and oxygen have separate but closely linked biogeochemical cycles that transform the elements between organic forms and inorganic forms. Healthy ecosystems retain most of the essential elements as immobilized organic compounds, with a portion contained in living organisms and about 4 to 5 times that amount as detritus. Soil microorganisms cycle a portion of the essential elements from organic detritus into inorganic forms each growing season. The quantity of essential elements mineralized by soil microorganisms determines the quantity of annual biomass production (Manske 2009, 2011a).

Soil organisms and plants use the essential elements in the inorganic form to synthesize vital organic compounds of carbohydrates, proteins, and nucleic acids. Grass plants produce double the quantity of leaf biomass than needed for normal plant growth (Crider 1955, Coyne et al. 1995). All of the aboveground herbage biomass produced by perennial grasses in a growing season represents about 33% of the total biomass produced. About 67% of the annual perennial grass biomass is produced belowground. About 50% of the aboveground biomass is expendable by the plant. About half of the expendable leaf material is removed as senescent leaves that are broken from the plant and fall to the ground, or as leaf material consumed by insects and wildlife. About half of the expendable leaf material, or 25% of the aboveground biomass, is consumed by grazing livestock (Manske 2012).

Perennial grass leaf material consists of digestible nutrients and nondigestible structural components. About 15% of the nutrients contained

in the consumed leaf material is extracted by stocker heifers and steers and retained for growth. About 30% of the nutrients contained in the consumed leaf material is extracted by lactating cows, with a portion retained by the cow for production, and the remainder of the extracted nutrients passed on to her calf for growth (Russelle 1992, Gibson 2009).

All of the nondigestible dry matter and most of the nutrients consumed by grazing livestock are deposited on the ground as manure in a couple of days. Most of the nutrients consumed and used by livestock for maintenance are returned to the ecosystem in the feces and urine. None of the herbage biomass dry matter produced during a growing season is removed by livestock from the grazingland ecosystem. All of the essential elements contained in the belowground biomass and contained in the nonconsumed aboveground biomass stay in the ecosystem. Nearly all of the essential elements used in the annual production of herbage biomass and soil organism biomass are retained and recycled in the ecosystem.

Some essential elements are lost or removed from the ecosystem as output. If the grassland ecosystem is burned, almost all of the essential elements in the aboveground herbage are volatilized, and if the soil is dry, some of the belowground essential elements are also lost (Russelle 1992). The metabolic process of respiration in soil organisms, plants, and animals results in a loss of some essential elements as carbon dioxide, water vapor, and heat energy. Some essential elements are removed from the ecosystem as weight biomass produced by insects and wildlife. The essential elements transferred from grass plants to grazing animals and used for animal growth are removed from the ecosystem (Gibson 2009).

The small proportion of the ecosystem essential elements that are lost or removed annually need to be replenished by capturing input essential elements through ecosystem processes. These ecological processes consist of energy (TDN) flow (table 1), nitrogen flow (table 2), and decomposition of organic matter (table 3). Atmospheric carbon dioxide is the ecosystem input for carbon.

Precipitation of water is the ecosystem input for hydrogen. Wet deposition of nitrogen oxides following lightning discharges is the ecosystem input for nitrogen. Carbon dioxide, water, and nitrogen oxides are the ecosystem input for oxygen. Radiant light from the sun is the ecosystem input for energy (Manske 2011b). The input sources of essential elements are not part of the ecosystem supply until the ecosystem processes capture the input essential elements (Manske 2012).

Ecosystem processes are inhibited from functioning at potential levels by antagonistic management practices preventing capture of essential elements from input sources at quantities adequate to replenish annually lost or removed elements. The resulting increasing deficiencies of essential elements cause decreasing production and ecosystem degradation (Manske 2012).

Perpetually sustainable grazingland ecosystems can be achievable with implementation of biologically effective management that activates all ecosystem biogeochemical processes and all grass plant physiological processes to function at potential levels. When these processes function above threshold levels, capture and replenishment of input essential elements occurs at greater quantities than the amount of output essential elements (Manske 2012).

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Table 1. Energy (TDN) flow.

Grazingland ecosystem energy flow includes three biogeochemical cycles: the carbon cycle, the hydrogen cycle, and the oxygen cycle.

Photosynthesis is the process that captures energy.
 $\text{CO}_2 + 2\text{H}_2\text{O} + \text{sunlight energy} + \text{green plants} \Rightarrow \text{CH}_2\text{O} + \text{O}_2$

Respiration is the process that releases energy.
 $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \Rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{heat energy}$

Table 2. Nitrogen flow.

Grazingland ecosystem nitrogen flow is primarily the nitrogen cycle and includes three other biogeochemical cycles: the oxygen cycle, the carbon cycle, and the hydrogen cycle.

Wet Deposition is the process that changes nitrogen from atmospheric forms to edaphic forms.
 $\text{N}_2 + \text{O}_2 + \text{lightning discharge} \Rightarrow \text{NO} + \text{N}_2\text{O}$ at 5 to 6 lbs/ac/yr = 3 to 8 tons/ac

Immobilization is the process that changes nitrogen from inorganic forms to organic forms (nucleic acids and crude proteins).
 $\text{NH}_4 + \text{NO}_3 + \text{grass plants} + \text{soil organisms} \Rightarrow \text{nucleic acids} + \text{amino acids} \Rightarrow \text{crude protein} + \text{organic compounds}$

Mineralization is the process that changes nitrogen from organic forms to inorganic forms (mineral nitrogen).
 $\text{Organic matter} + \text{saprophytes} \Rightarrow \text{NH}_3 + \text{CO}_2$
 $\text{NH}_3 + \text{H} \Rightarrow \text{NH}_4$
 $2\text{NH}_4 + 3\text{O}_2 + \text{Nitrosomonas} \Rightarrow 2\text{NO}_2 + 2\text{H}_2\text{O} + 4\text{H} + \text{energy}$
 $2\text{NO}_2 + \text{O}_2 + \text{Nitrobacter} \Rightarrow 2\text{NO}_3 + \text{energy}$

Table 3. Decomposition of organic matter.

Grazingland ecosystem organic matter decomposition includes all of the biogeochemical cycles.

Decomposition is the process that changes complex organic matter into compounds and then into the elemental forms.

Dead organic matter + saprophytes \Rightarrow 150% microbe biomass + CO_2 + H_2O + minerals

Compound Composition		Elemental Composition	
Carbohydrates	60%	Carbon	44%
Sugars and Starches	1-5%	Oxygen	40%
Hemicelluloses	10-30%	Hydrogen	8%
Cellulose	20-50%	Minerals	8%
Lignins	10-30%		
Fats, Waxes, Tannins	1-8%		
Protein	1-15%		

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