Grazingland Management Impacts on Light-Use-Efficiency

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Q1: **Can pastures under intensive rotational grazing be distinguished from pastures that are managed less-intensively using remote sensing?**

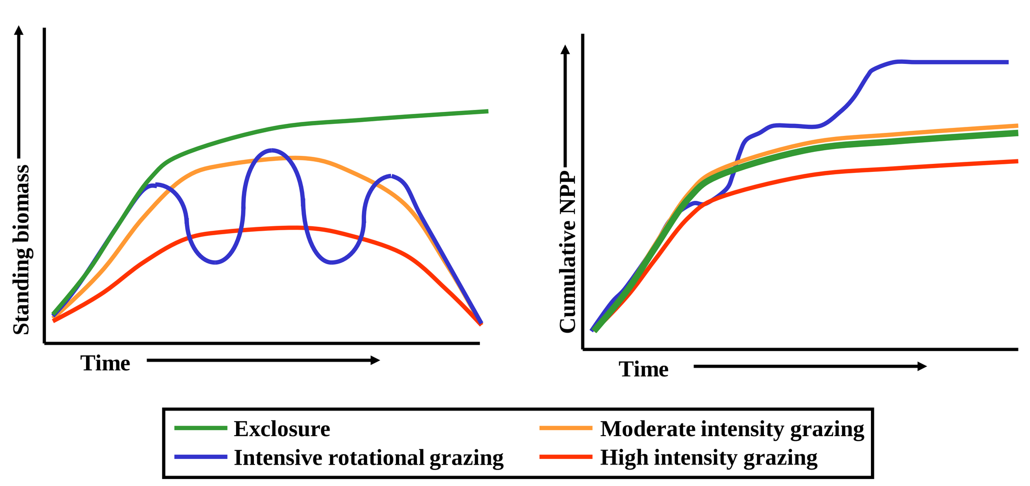
H1: **Pastures under intensive rotational grazing are (1) more productive (higher NPP) and (2) have different seasonal distribution of aboveground biomass and can, thus, be distinguished from from extensively managed pastures remotely.**

Intensive rotational grazing: Effects on biomass, NPP

Intensive rotational grazing is widely believed to increase grassland forage production by ensuring more uniform forage removal and allowing a recovery period. A recent review found that rotational grazing in dry rangelands does not influence forage production, but in more humid regions, forage production increased by 20-30%. There is a long history of using rotational grazing to increase production and in some areas, such as New Zealand and Australia, rotational grazing is widely used. However, the use of rotational grazing in the southeastern United States has not been well researched.

A key component of the benefit of intensive rotational grazing is more efficient use of forage that is produced. More frequent forage removal keeps plants from reaching slower growth phases associated with leaf maturity. Therefore, while intensive rotational grazing increases annual forage production, standing aboveground biomass may actually be equal or greater under traditional, non-rotational grazing. Seasonally integrated or one-time measurements of vegetation indices, such as the Normalized Difference Vegetation Index (NDVI) or soil adjusted vegetation indices (SAVI) are unlikely to be useful in identifying pastures under intensive grazing management. However, more frequent measurements throughout the growing season would enable quantification of changes in biomass over time and total biomass production.

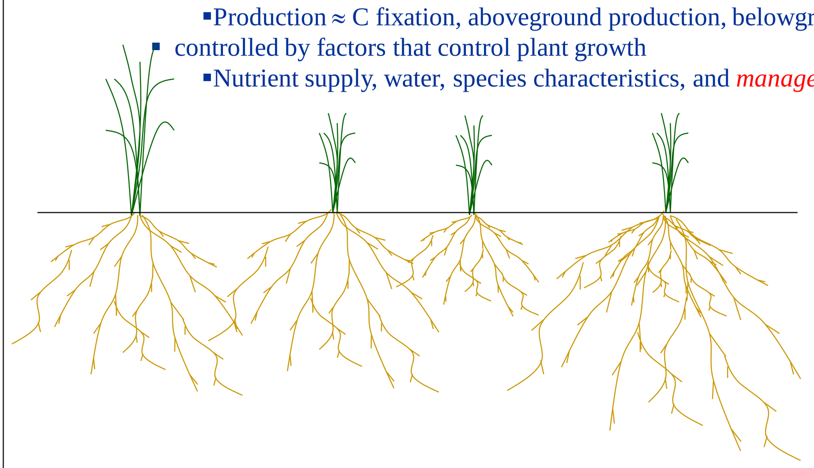
Removing aboveground biomass through grazing reduces LAI and APAR and should affect NDVI. Grazing decreases the gross photosynthetic capacity of plants, but prompts compensatory photosynthetic rates in remaining tissue exceeding that in ungrazed plants of the same age. Reduction of photosynthetic capacity following defoliation can occur if damage is substantial or recurring, but defoliation through grazing generally slows or reverses declines in photosynthetic capacity associated with leaf senescence. Thus, the immediate effects of grazing are to decrease APAR and to increase ε, both of which are important components for estimating NPP using remote sensing.



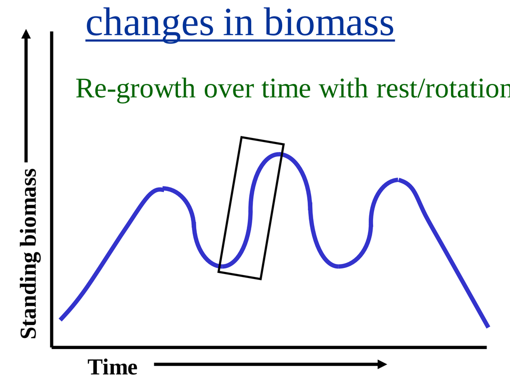
NPP = APAR * ε

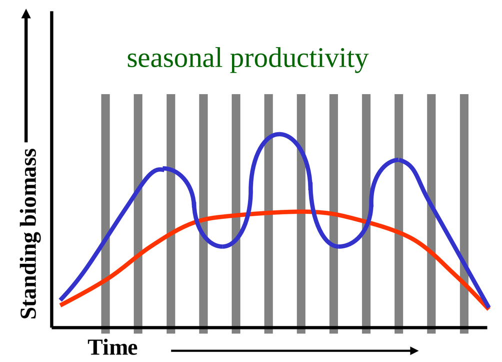
APAR = Absorbed Photosynthetically Active Radiation
- f (incoming radiation – reflected radiation)
- ∝ Leaf area index (LAI)

ε = Light-use-efficiency
- varies (spatially and temporally) and can't be measured remotely
- units some variation of production/radiation
  - Production ≈ C fixation, aboveground production, belowground production, etc.
- controlled by factors that control plant growth
  - Nutrient supply, water, species characteristics, and *management*

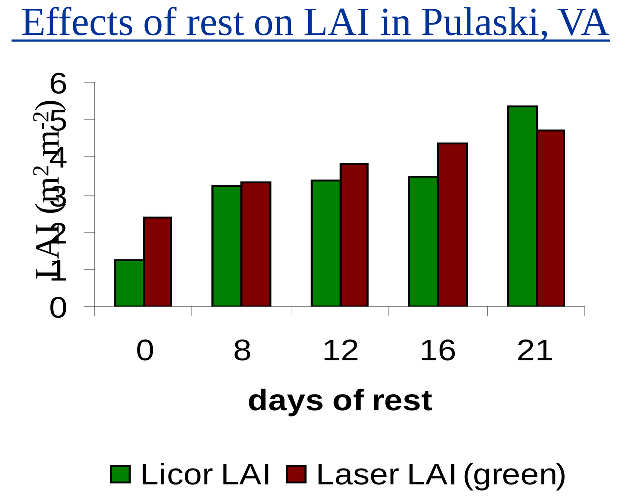


Intensive rotational grazing: changes in biomass

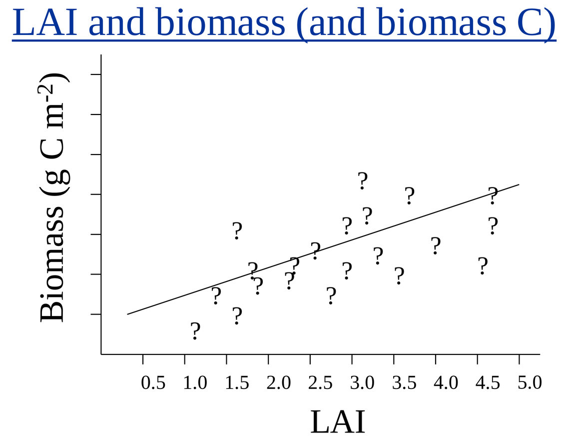


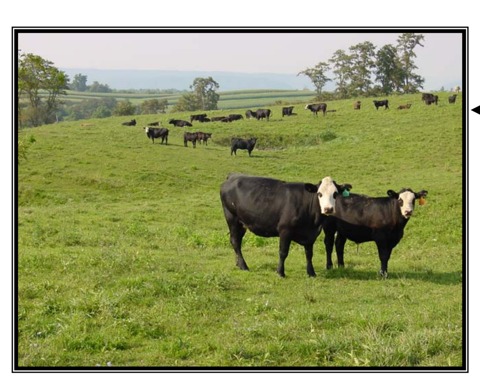


Intensive rotational grazing: Effects of rest on LAI in Pulaski, VA



We will derive a relationship between LAI and biomass (and biomass C)





Pulaski, Virginia
- rotational grazing
- soil C + root biomass (pasture project)
- clipping experiment
- LAI, clipping after rest period
- seasonal LAI, clipping, root biomass

Spartansburg, Tennessee
- rotational grazing + fertilization
- soil C + root biomass (pasture project)
- clipping experiment
- LAI, clipping after rest period

Q2: **Can grazing intensity on extensively managed rangeland be quantified using remote sensing?**

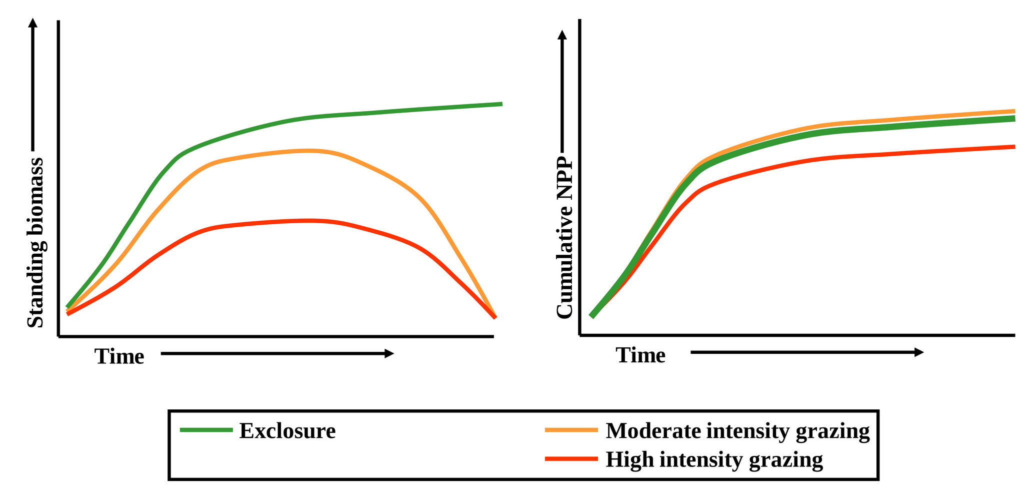
H2: **Rangeland sites with similar climate and grazing history have similar production potentials that are modified by current grazing intensity which affects LAI and is, thus, amenable to detection by remote sensing.**

Grazing intensity: Effects on biomass, NPP

In many cases grazing leads to decreased NPP, but under certain conditions rangeland grazing of moderate intensity (30-50% of NPP consumed) in grasslands can increase NPP by as much as 10%. When overcompensation occurs, the magnitude of plant NPP response is very likely to be less than the proportion of NPP removed, seasonally distributed, and interannually variable. Grazing, therefore leads to decreased standing biomass, LAI and APAR, even when grazing results in increased NPP. I hypothesize that the seasonal pattern of biomass production and standing biomass follow seasonal patterns like those illustrated below.

Remote sensing of rangeland management has been used with varying degrees of success. Results from work at the Konza Prairie Long Term Ecological Research (LTER) site attempting to identify patterns of grassland management using remote sensing were somewhat confounded by seasonal influences, the amount of standing dead biomass, and changes in the amount of ground cover. Others have successfully used SPOT data to distinguish grassland fields under different types of mowing and grazing management. Others have used remotely sensed biomass data to verify cattle distribution in semiarid rangelands in Australia. Likewise, near-IR radiance has effectively been related to sheep population density in England and grassland yields have been successfully estimated using remote sensing.

Remote sensing of rangeland management has been compounded by four main problems: (1) sample frequencies long enough to preclude detection of impacts of grazing, (2) variability of ε in response to grazing, (3) difficulty distinguishing standing dead vegetation, and (4) confounding variability due to topography. Recent developments in remote sensing technology (MODIS) that produce more frequent moderate resolution measurements of variables important in estimating NPP (i.e. NDVI, SAVI) will provide data frequently enough to overcome problems associated with infrequent re-sampling. Ground-based parameterization of spatial and seasonal variation in ε are a necessity of relationships between spectral characteristics and NPP since ε varies with seasonally and with management.

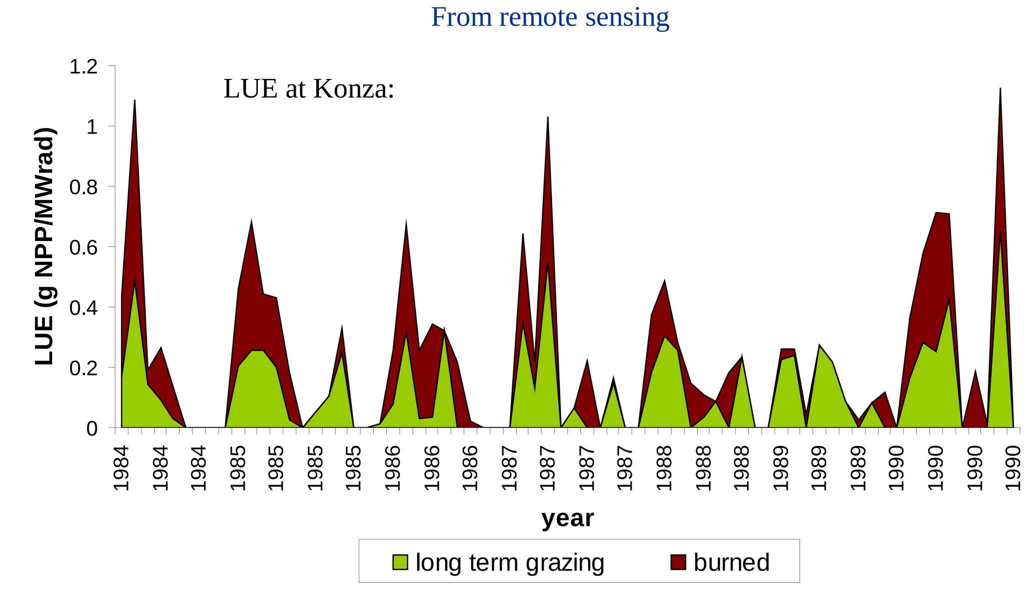


Grazing intensity in rangelands: biophysical effects

- Spatial, seasonal, inherent variability
- End of season above-ground biomass
- Intensive study sites:
  - CPER (SGS LTER)
  - Jornada LTER
  - Crescent Lake Nat'l WR
- Clipping/field-based measurements
- Management-induced differences in
  - LAI
  - LUE
  - NPP_a
  - NPP_b

Rangeland productivity, LUE, and effects of management

From published data (IBP)
From sampling
From remote sensing



Jornada LTER
(USDA Jornada Experimental Range)

Short grass steppe LTER
(USDA Central Plains Experimental Range)

Crescent Lakes National Wildlife Refuge

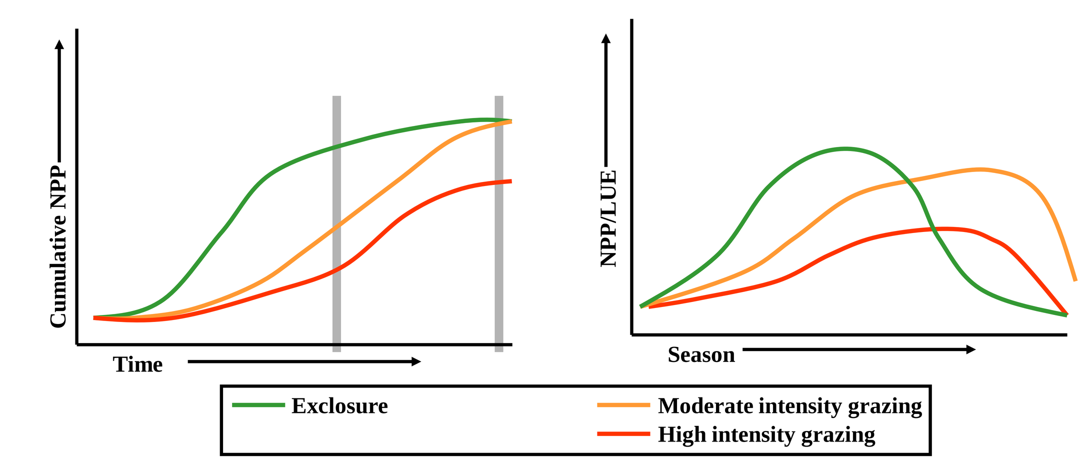
Q3: **Can rangeland under long-term grazing exclosure and different grazing intensities be distinguished using remote sensing?**

H3: **Long-term grazing treatments of varying intensity differentially affect LAI and can therefore be identified using remote sensing.**

Historical grazing in rangelands: effects on NPP

Rangeland degradation through overgrazing is a global problem, the extent of which has been quantified only using large-scale survey data. Rangeland degradation as a result of overgrazing leads to many environmental problems including soil erosion, changes in species composition, and, perhaps most importantly for producers, decreased production potential. Identifying impacted rangelands, therefore, has important ecological, economic, and policy implications.

Evidence of rangeland degradation via remotely sensed parameters could include decreased NDVI and SAVI, increased soil reflectance, decreased peak biomass, or altered seasonal distribution of standing crop. Determination of rangeland condition, production, and/or productivity using remote sensing have been attempted using a variety of methods with varying success. For example Landsat-TM measurements of LAI agreed well with ground based measurements. Others have had success quantifying impacts of grazing in Australian rangelands with NDVI or SAVI. Multi-temporal NDVI or SAVI can, therefore, be used to identify grasslands that (1) have been adversely impacted by grazing, (2) are progressing away from a degraded stage, and (3) are degrading due to poor management.



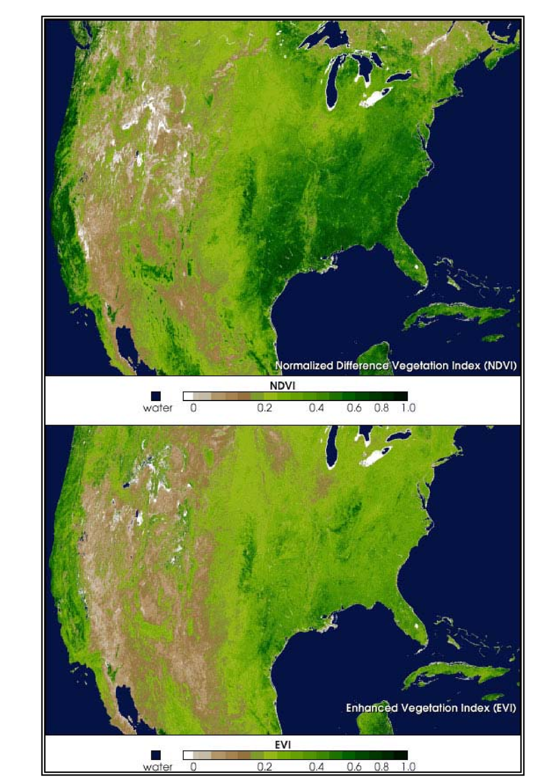
- Changes in species composition (C4 shifts) in response to grazing should be manifest in seasonal distribution of NPP
- Seasonality of NPP is detectable using remote sensing
- Therefore, historical grazing intensity is amenable to remote sensing

MODIS land cover products

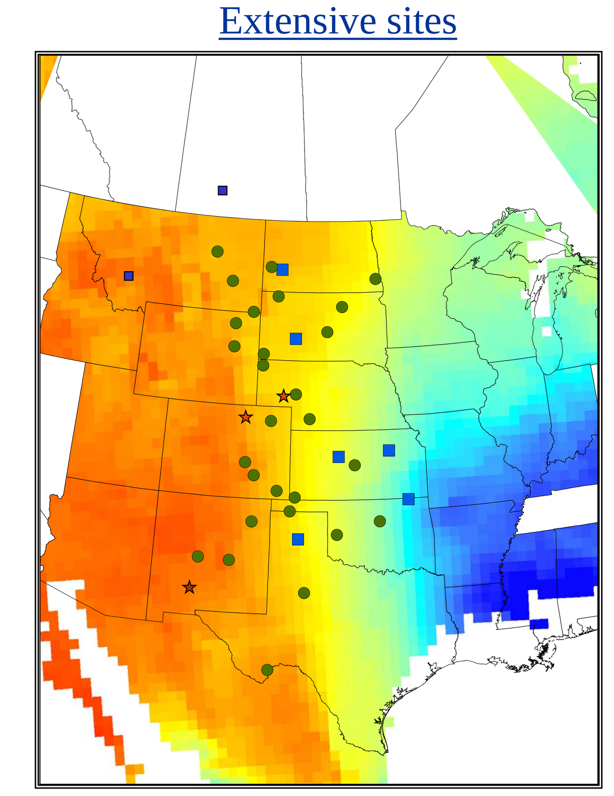
(moderate resolution imaging spectrometer)
- NDVI
- LAI
- APAR
- Albedo
- Snow cover
- NPP

Positives:
- 250/1000m resolution
- 8 day intervals
- Standard format (HDF)
- Bands correspond with LANDSAT
- *No charge!*

Negatives:
- New instrument (no historic data)
- Problems w/ yr 1 data
- Standard format (HDF)



Extensive sites



- Grazing exclosures/treatments
- Grazing history
- Neighboring ranches w/ grazing
- Species composition data
- National grasslands
- National wildlife refuges
- ARS Experimental ranges
- LTER sites
- National parks
- National/state historic sites

Integrated:
Multiple sources of data:
- **Current**
- **Historic**
- **Land-based**
- **Remotely sensed**

Integrates measurement and modeling

Multi-scale:
- **Spatial:**
  - **Fine-scale ground-based data**
  - **Coarse-scale RS data**
- **Temporal:**
  - **Very frequent measurements**
  - **Historical measurements**

Grassland management:
- **Remote sensing techniques for present and historical grazing management**
- **Impacts on NPP, LUE**

Implications for C cycling: