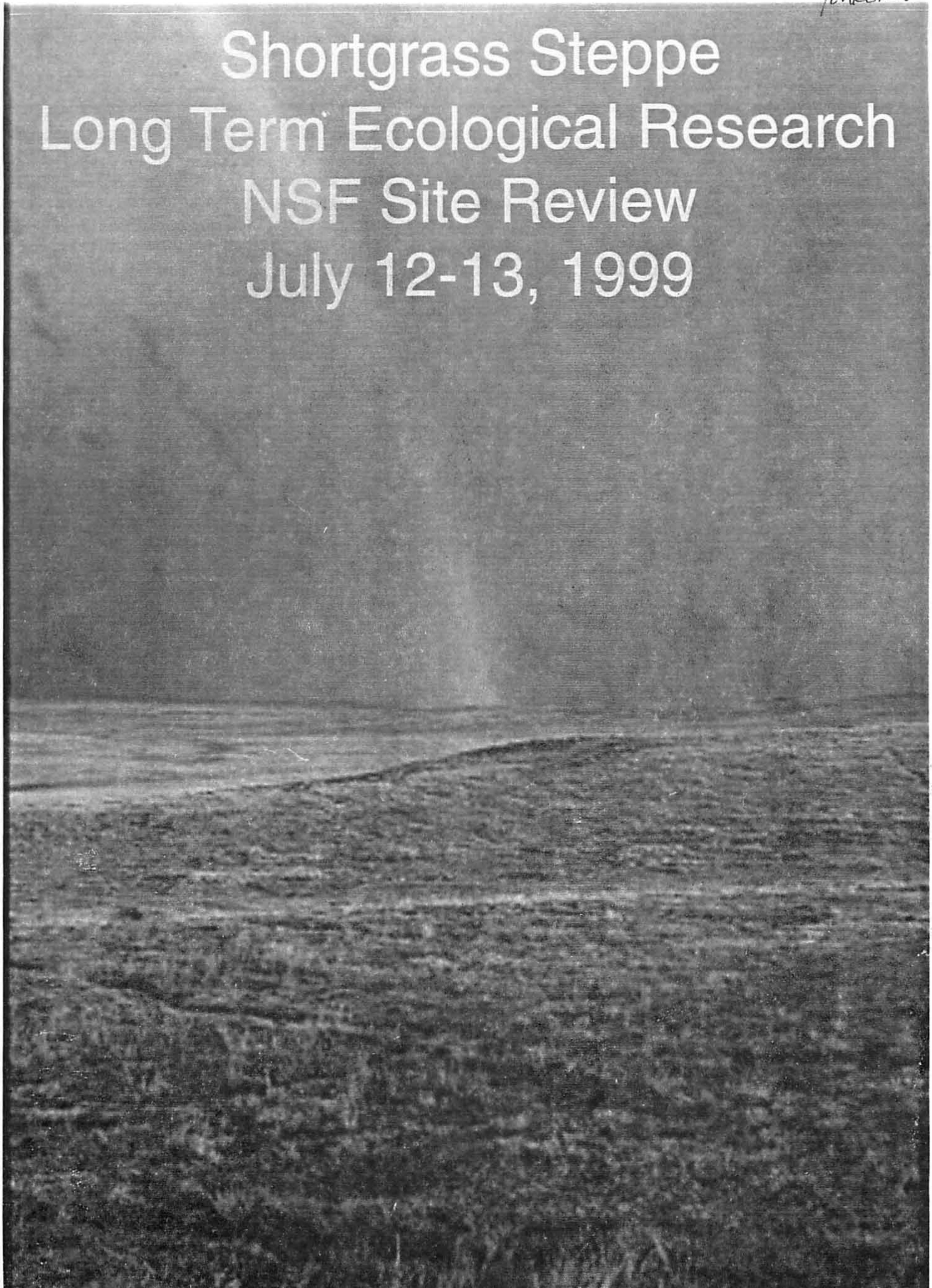
# Shortgrass Steppe Long Term Ecological Research NSF Site Review July 12-13, 1999



<u>**Agenda for SGS Site Review**</u>

<u>**Sunday, July 11th**</u>

Late afternoon, site review team arrives

**6:45** Meet at Holiday Inn Lobby for ride to Dinner

**7:00** Dinner, site review team with all PI's

<u>**Monday, July 12th**</u>

**7:00** Breakfast, Site Review Team Meets

**7:45** Meet at Holiday Inn Lobby

**8:00** Van leaves from Holiday Inn for SGS Field Headquarters

**9:00** Welcome and Comments:

Dr. Jud Harper, Vice President For Research, Colorado State University

Dr. Arvin Mosier, for the USDA-Agricultural Research Service Central Plains Experimental Range, Rangeland Research Unit

Denver Burns, USDA-Forest Service Rocky Mountain Research Station Director

Steve Currey, Pawnee National Grasslands District Ranger

**9:30** Introduction to the SGS LTER – Indy Burke

**10:30** Break and Questions

**11:00** Atmosphere – Ecosystem Interactions

Dr. Roger Pielke, Sr.: Atmosphere-ecosystem interactions

Dr. Gene Kelly: Paleoclimate and paleopedology

Dr. Bill Parton: Long term data analysis and modeling

**12:00** Lunch in the cottonwoods (box lunches provided)

Brandon Bestelmeyer, Bob Schooley, invertebrates in the shortgrass steppe

**1:00** Grazing and small mammal herbivory

Dr. Daniel Milchunas

Dr. Jim Detling

**2:00** Enhanced $CO_2$ Experiment

Dr. Arvin Mosier

Dr. Dan LeCain

Dr. Dan Milchunas

**3:00** Prairie Dogs

Dr. Bea Van Horne

Jeanine Junell

Dr. Jim Detling

Dr. Paul Stapp

**4:30 – 6:00** Poster session/cocktail hour and meeting with graduate students and undergraduate students

**6:00** - Barbecue with all the investigators and students working on the shortgrass steppe, then back to the Holiday Inn

**<u>Tuesday, July 13</u>**

**7:30 – 8:30** Executive Session of Site Review Team over Breakfast

**8:30** Information Management/GIS

Chris Wasser

Martha Coleman

**9:00** Education and Outreach

Dr. John Moore/Indy Burke

**9:15** Presentation/Discussion of our Leadership Structure/Administrative Connections (All)

**10:00** Break

**10:30 – 12:30** Site Review team meets with the key administrators:

**10:30** Dr. Jud Harper, VP for Research, CSU

**11:00** Denver Burns, USDA Forest Service Rocky Mountain Research Station Director

**11:30** Dr. Will Blackburn, Area Director USDA-ARS

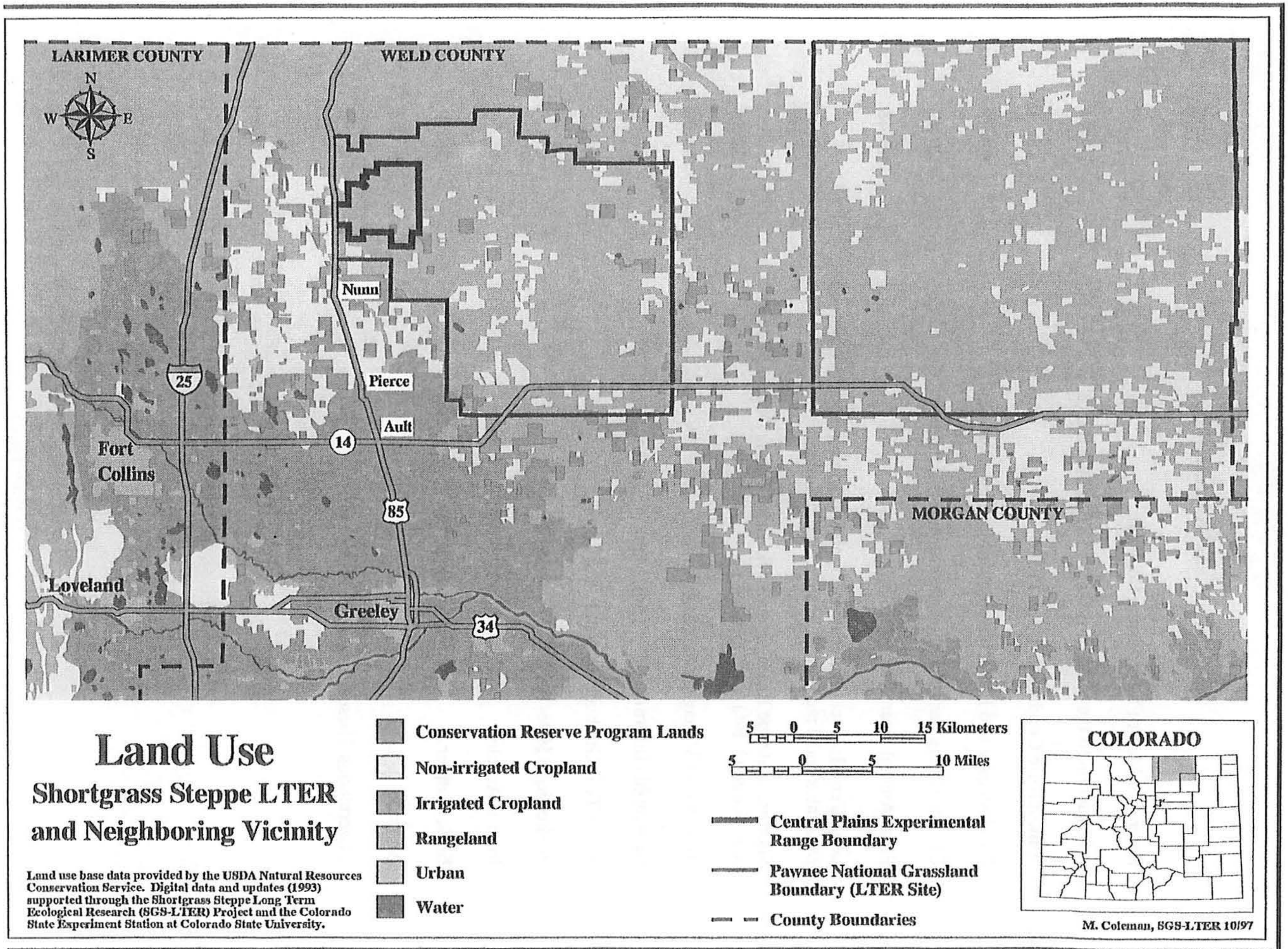
**12:00** Al Dyer, Dean, College of Natural Resources

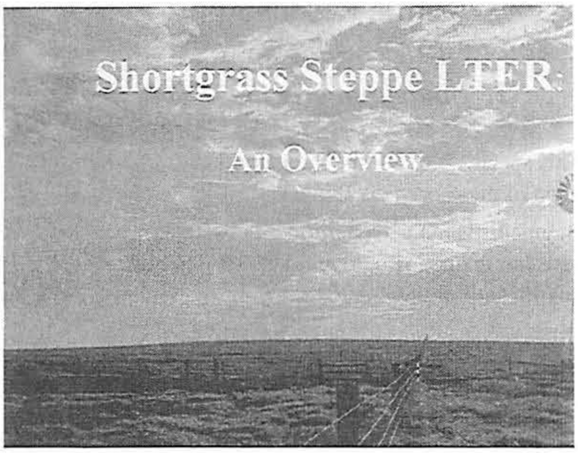
Susan Stafford, Department Head, Forest Sciences

Dennis Child, Department Head, Rangeland Ecosystem Sciences

**12:30** Box lunches and the Site Review Team in Executive/Report Writing Session

## Table of Contents


LARIMER COUNTY
WELD COUNTY
N
W
E
S
Nunn
Pierce
Ault
25
14
85
34
Fort Collins
Loveland
Greeley
MORGAN COUNTY
Land Use
Shortgrass Steppe LTER and Neighboring Vicinity
Land use base data provided by the USDA Natural Resources Conservation Service. Digital data and updates (1993) supported through the Shortgrass Steppe Long Term Ecological Research (SGS-LTER) Project and the Colorado State Experiment Station at Colorado State University.
Conservation Reserve Program Lands
Non-irrigated Cropland
Irrigated Cropland
Rangeland
Urban
Water
5 0 5 10 15 Kilometers
5 0 5 10 Miles
Central Plains Experimental Range Boundary
Pawnee National Grassland Boundary (LTER Site)
County Boundaries
COLORADO
M. Coleman, SGS-LTER 10/97




## Overview

- A brief project history (1982-1995)
  - Research foci
  - Key scientific results
  - Publications and synthesis products
- The current project
  - Our site
  - Conceptual Framework
  - Current research foci
  - How does it fit together?
  - How do we prioritize our work?
  - Structure of the project
  - Recent progress and publications
  - Synthesis, network, and cross-site activities and products
  - Agenda for the site review

## Brief Project History

- *For an LTER, the past is a key part of our current and future work*
- Age of IBP: 1968 - 1974
- LTER first funded in 1982 (Woodmansee (CSU), Lauenroth (CSU), and Laycock(ARS))
- Site: The Central Plains Experimental Range

## Research Focus

- Our research focus over the past 17 years has been to understand the processes that account for the origin and maintenance of structure and function in shortgrass steppe (SGS) ecosystems.

## Research Focus

***The key questions that continue to organize and guide our research are:***

- **1. How are the distribution and abundance of biotic components of the SGS maintained through time and over space?**
- **2. To what factors are the distribution and abundance of biotic components vulnerable?**
- **3. How do changes brought about by these factors influence biological interactions and ecosystem structure and function?**

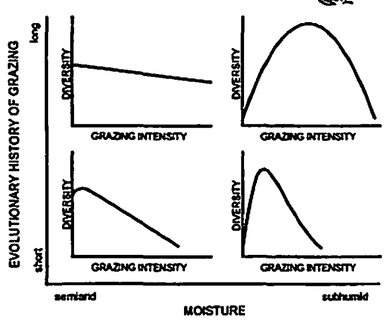
## Key Scientific Foci 1982-1995

- *grazing ecology and disturbance*
- *net primary production (above and belowground)*
- *ecology of Bouteloua gracilis*
- *field and simulation analysis of biogeochemistry*
- *landscape ecology (with a catena focus)*
- *regional analysis*
- *Short- and long-term climatic variability*

## Key Scientific Results from 1982-1995

### 1. Grazing ecology

- **Grazing is an important part of the evolutionary history of the shortgrass steppe; there are important adaptations to grazing.**
- **(Milchunas et al. 1988, and many others)**




## Key Scientific Results from 1982-1995

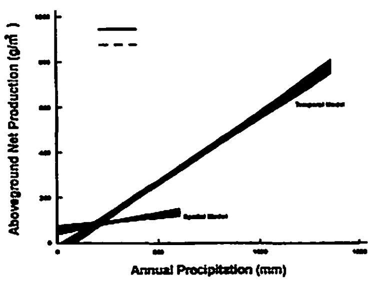
### 2. *Bouteloua gracilis*

- This species is by far the most dominant plant of the shortgrass steppe
- B. gracilis is long-lived, drought resistant, resistant to grazing, and recovers slowly but significantly following disturbance

## Key Scientific Results from 1982-1995

### 3. Net primary productivity

- Aboveground NPP is controlled largely by precipitation (Lauenroth and Sala 1992)




## Key Scientific Results from 1982-1995

### 3. Net primary productivity

- Belowground NPP represents a smaller proportion of total NPP than previous (IBP) results had suggested; isotopic techniques suggest belowground is 1-1.5 x aboveground NPP (Milchunas and Lauenroth 1992)

## Key Scientific Results from 1982-1995

### 4. Field and Simulation Analysis of Biogeochemistry

- Development of Century model (Parton et al 1987, co-supported by the Cole et al. NSF Great Plains project)

## Key Scientific Results from 1982-1995

### 4. Field and Simulation Analysis of Biogeochemistry

- The location of individual plants represents an important control over soil organic matter pools and nutrient availability (Burke et al. 1995, Vinton and Burke 1995)

## Key Scientific Results from 1982-1995
### 5. Landscape Ecology

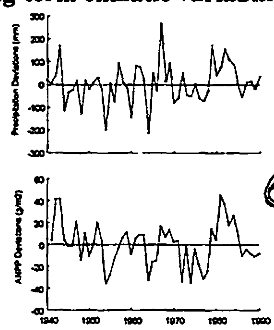
- A 2-dimensional representation of the landscape is insufficient for explaining topographic variability in soil organic matter; soil formation is highly dependent upon wind, parent material, and paleo-history which are 3-dimensional forces (Yonker et al. 1988)

## Key Scientific Results from 1982-1995
### 6. Regional analysis

- **Regional patterns in NPP, soil organic matter, vegetation, and landuse are strongly controlled by gradients in precipitation, temperature, and soil texture (Sala et al. 1988, Burke et al. 1989, 1991, etc).**
- **Supported initially by LTER supplements, more recently by other grants in collaboration.**

## Key Scientific Results from 1982-1995
### 7. Short- and long-term climatic variability

- **Over the past century, the shortgrass steppe has been vulnerable to large fluctuations in annual precipitation, which is the key control over NPP and thus many ecosystem functions (Lauenroth and Sala 1992)**



## Key Scientific Results from 1982-1995
### 7. Short- and long-term climatic variability

- **Over the past 10,000 years, the shortgrass steppe has experienced large changes in precipitation and temperature that have altered vegetation structure, soil organic carbon, and landscape structure (Kelly et al. 1993).**

## Publications from the LTER 1983-1995:

- Primary scientific results from the SGS-LTER from 1983-1996 were published in many journals spanning many disciplines

| | Total | Pure LTER |
|---|---|---|
| Journal Articles | 579 | 100 |
| Book Chapters | 163 | 15 |
| Abstracts | 327 | 46 |
| Dissertations/Theses | 139 | 16 |

## Sample of Journals

- **Nature**
- **Science**
- **Ecology**
- **Ecological Monographs**
- **Ecological Applications**
- **Journal of Ecology**
- **American Naturalist**
- **BioScience**
- **Oecologia**
- **Oikos**
- **Journal of Range Management**
- **Plant and Soil**
- **Landscape Ecology**
- **Ecological Modeling**
- **American Journal of Botany**
- **Soil Science Society of America Journal**
- **and many others**

## Publications from the LTER 1983-1995

- Synthesis products from the SGS-LTER from 1983-1995 were published in many books and other fora.

## Examples:
### Ecology of the shortgrass steppe and comparable grasslands

- Milchunas et al. 1988. Effects of grazing on global grasslands
- Lauenroth and Milchunas 1991. Ecology of the shortgrass steppe
- Lauenroth and Coffin. 1992. Grasslands, belowground processes, and recovery from disturbance
- Coffin et a. 1993. Spatial processes and recovery in grasslands
- Lauenroth et al. 1994 Effects of livestock grazing the Great Plains).
- Lauenroth and Burke 1995. Climatic variability in the Great Plains.

## Examples: Simulation analysis of C in grasslands

- Parton et al. 1987: Controls over soil organic matter dynamics (development of Century)
- Burke et a. 1990. Regional modeling of grasslands using GIS.
- Parton et al. 1993:.Observations and modeling of biomass and soil organic matter dynamics for the grassland biome worldwide .
- Burke et al. 1994. Interactions of landuse and ecosystem function in the Great Plains.
- Coleman et al. 1994. Linking simulation models to geographic information systems.

## Cross-site analysis

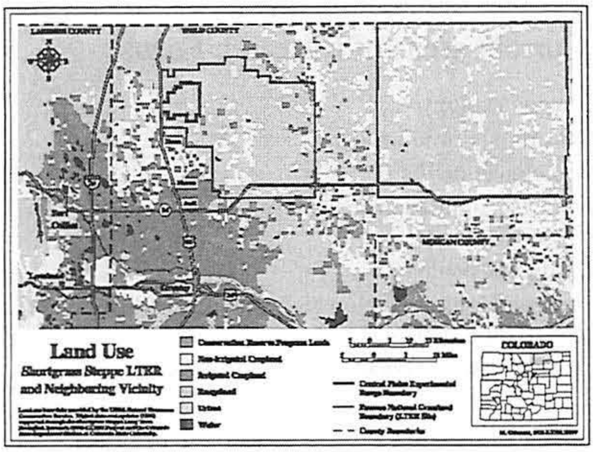
- Sala et al. 1988. Regional analysis of net primary productivity
- Burke et al. 1989. Regional analysis of soil C and N.
- Moore et al. 1993 . Influence of ecosystem productivity on the stability of real and model ecosystems
- Burke et al 1991. Regional analysis of the Central Great Plains: Sensitivity to climate variation.

## **The Current Project 1996-1999**

- ***Our site***
- ***Conceptual Framework***
- ***Current research foci***
- ***How does it fit together?***
- ***How do we prioritize our work?***
- ***Structure of the project***
- ***Recent progress and publications***
- ***Synthesis, network, and cross-site activities and products***
- ***Agenda for the site review***

## Site

- In 1996, we expanded the definition of our "site" to include the entire Pawnee National Grasslands as well as the Central Plains Experimental Range (6500 ha to 84,000 ha).
- The environmental variation within our new site represents approximately 23% of the U.S. shortgrass steppe.
- Expansion is a slow process with a flat budget!
  - Primarily paleopedology, prairie dog, and fire ecology work to date.




## Conceptual Framework

- **Our conceptual framework asserts that one must consider the interplay of several forces, which occur at a variety of spatial and temporal scales, in order to understand the structure and function of SGS ecosystems. There are five components that we have identified as particularly important in shaping the SGS:**
  - atmospheric conditions,
  - natural disturbance,
  - physiography,
  - human use, and
  - biotic interactions.
- **Below, we provide an overview of the SGS in order to frame the unique interactions of these components, and then elaborate on each in turn.**

## Conceptual Framework

- 1. The shortgrass steppe is unique among North American grasslands for its long evolutionary history of intense selection by both drought and herbivory, leading to an ecosystem that is very well adapted to withstand grazing by domestic livestock

## Conceptual Framework

- 2. The distinctive features of the SGS are:
  - a) **its vegetation**
  - which is both drought and grazing resistant,
  - and which is strongly dominated by one species;

## Conceptual Framework

- b) **the strong concentration of biological activity and organic matter belowground**, such that
- most of the energy in the system flows belowground,
- most carbon and other elements are stored belowground,
- and the system is relatively resistant to aboveground disturbances (grazing, fire) but vulnerable to disturbances that target the soil system (cultivation);

## Conceptual Framework

- c) a strong evolutionary/historical importance of aboveground grazers that are no longer so prevalent, including bison, prairie dogs, elk, deer, pronghorn, and bighorn sheep.

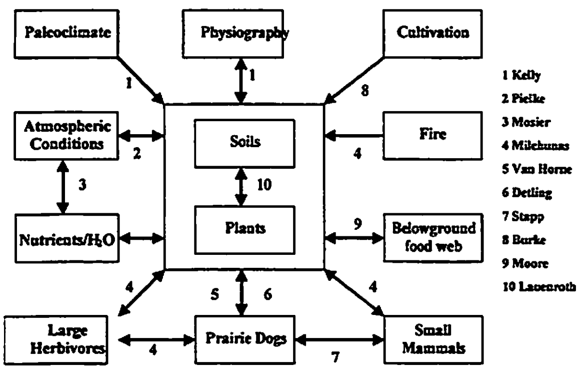
## Conceptual Framework

- 3. Because of these features, the shortgrass steppe is particularly vulnerable to landuse management and atmospheric changes that alter the abundance/composition of herbivores, the plant species composition, and the distribution and cycling of elements in soils.

## Current areas of Research Focus

- Grazing ecology
- Net primary productivity
- Bouteloua gracilis
- Field and simulation analysis of biogeochemistry
- Landscape ecology
- Short and long-term climatic variability and ecosystem function
- Small Mammal Dynamics/keystone species

## How does it fit together?




## How do we prioritize our work? Which biotic interactions do we study?

- ***Those crucial to the structure and function of the shortgrass steppe today or in the past:***
- ***Dominant species***
  - ***Bouteloua gracilis, Buchloe dactyloides***
- ***Dominant flowpaths***
  - ***aboveground herbivory,***
  - ***belowground trophic dynamics***
- ***Keystone species (those that have important impacts on ecosystem structure and function but have low biomass levels)***
  - ***cactus; prairie dogs***

## How do we prioritize our work? Which biotic interactions do we study?

- ***Processes related to the key vulnerabilities of the SGS (landuse, atmosphere)***
- ***Processes important to larger-scale dynamics and interactions (trace gas flux, carbon balance)***
- ***Processes and dynamics that are important to the SGS and in which we have expertise***

## Structure of the Project

- Who are we? How is the work accomplished? How is the budget spent?

## Principal Investigators (10-15%)

13, 2 with leadership role

- Burke, I. C. (CSU, Dept Forest Sciences)
- Lauenroth, W. K. (CSU, Dept Rangeland Ecosystem Sciences)
- Bergelson, J. (U. Chicago)
- Coffin, D. * (ARS, New Mexico)
- Detling, J. K. (CSU, Dept Biology)
- Kelly, E. F. (CSU, Dept Soil and Crop Sciences)
- Milchunas, D. G. (CSU, Dept Rangeland Ecosystem Science and NREL)
- Moore, J. C. (Univ. Northern Colorado)
- Mosier, A. R. (ARS)
- Parton, W. J. (CSU, Dept Rangeland Ecosystem Science and NREL)
- Pielke, R. A. (CSU, Dept Atmospheric Sciences)
- Sala, O. E. *(Univ. Buenos Aires)
- Van Horne, B. (CSU, Dept Biology)
- (primarily collaborators at this time)

## Technical Support Staff (~45-55%)

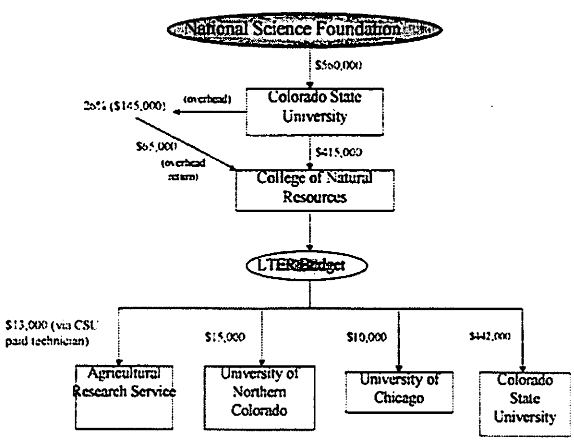
- **1 fulltime project manager/data manager (Chris Wasser)**
  - **part-time data management support (student hourly and workstudy)**
- **1 fulltime site manager (Mark Lindquist)**
- **1 fulltime administrative assistant/secretary**
- **3/4-time lab technician**
  - **lab processing**
- **1/2-time GIS person**
- **1/2 time programmer**
- **1/2 time field/lab support for trace gas work**
- **-1/4 time paleopedology/physiography person**
- **~6 person field crew**
- **1/2 time programmer/postdoc for mesoscale modeling**

## Graduate Students (~12-15% across all institutions)

- 7 supported directly off the grant (1 at UNC, 1 at U. Chicago; 2 at CSU have TA's, get LTER support for summer only, other 3 at CSU).
- at any time, 3-4 supported by NSF/NASA/etc fellowships (currently 3)
- 5-10 other associated graduate students from other grants closely related

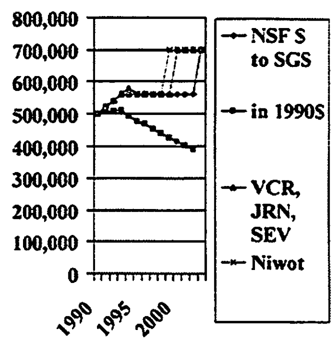
## Other

- Field and Lab analysis, Supplies, Services, and Travel: 12-20%
- Equipment Maintenance, upgrade: < 1%




## Budget History

- The budget has been flat since 1993, and will remain flat through 2002.
- The flat budget imposes constraints for a long term project.
- In 1993, following the site review, we planned an expansion of activities commensurate with planned budget increases which did not occur.
- By 2002, other sites will have received between 560,000 and 420,000 more than us since 1990



## Recent Progress (1996-9)

- science fronts and accomplishments (to be seen today)
- publications
- Synthesis-cross site-network accomplishments
- graduate students
- undergraduate students
- education
- data management

## Recent Accomplishments: A sample Grazing Milchunas et al. 1998

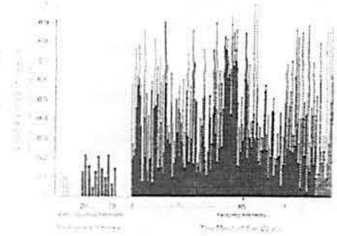


Fig. 1. Change in shortgrass steppe plant community composition due to grazing compared with other systems around the world. Other aboveground disturbances, such as fire, also have relatively little impact on shortgrass steppe.

## Recent Accomplishments: Grazing

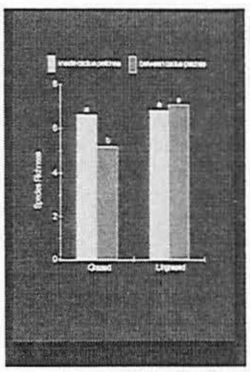
- Grazing influences organisms differentially, depending upon the individual class and species.
  - For instance, some birds increase in response to heavy grazing (the threatened species Mountain Plover), and others decrease (chestnut collared longspurs).
  - Milchunas et al. 1998

## Recent Accomplishments: Grazing

- Belowground food web structure is significantly altered by grazing:
  - 5-10 years is sufficient to completely change the belowground food web structure when changing from grazed to ungrazed, or vice-versa
  - (Moore et al in prep)

## Recent Accomplishments: Grazing

- Plains prickly pear cactus creates a refugia effect in grazed areas for non-grazing resistant plant species (REU project, Bayless, Lauenroth, and Burke)



## Climatic variability: Recent Accomplishments/Scientific Progress Kelly et al. 1998, Becker et al. 1997

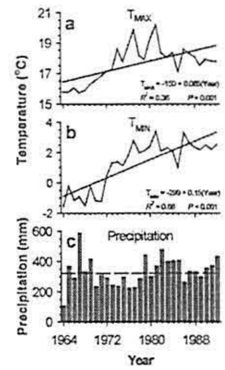
- 1) Higher proportions of $C_3$ vegetation persisted at the early Holocene. The concordance in the C isotopic signatures of soil organic matter and phytolith provide strong biological evidence of regionally cooler conditions.

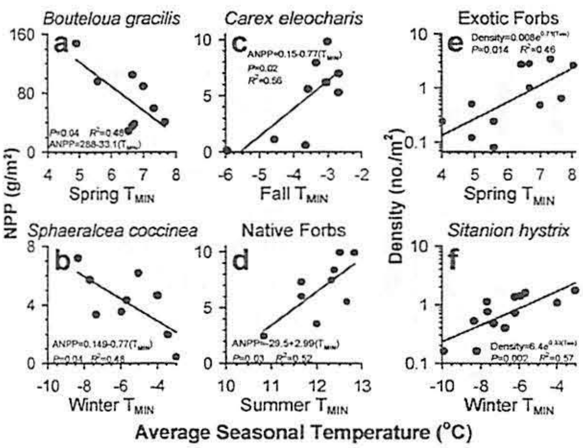
- 2) C isotope concordance also appears during the mid-Holocene soil forming interval; C isotope values indicate an increase in the proportion of $C_4$ vegetation, which reflect regionally warmer climatic conditions than present.

Strong climatic variability over past 500 years (REU project with Lauenroth)

## Climatic Variability

- Alward et al. 1999 Science article: Grassland vegetation changes and nocturnal global warming.
- Results utilized long-term LTER data set.




## Recent Results:Climatic Variability

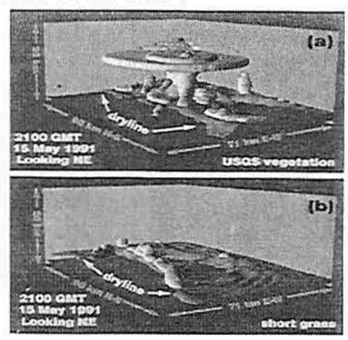
- Newest results suggest the warming signal may be very local in extent (Parton et al and Pielke et al.: analysis of long-term data sets)
  - Max summer temperatures are decreasing, minimum summer temperatures are increasing
  - Summer wind speeds are decreasing
  - There is more rainfall recently, and greater snow cover
- Vegetation exerts a major control over weather:
  - Vegetation is a key component of climate!

## Recent Results: Climatic Variability

- Increases in soil temperature do not influence aboveground NPP, soil respiration, N mineralization, and decomposition, and do not have a clear influence on trace gas flux. (Lauenroth and Burke in prep: )
- Increases in water and N availability increase aboveground NPP and soil respiration, and increase $N_2O$ flux. (Lauenroth, Burke, and Mosier in prep)

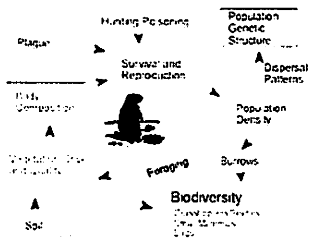
## Recent Results: Climatic Variability Pielke et al. 1997

Landuse management In the region has a strong Influence on mesoscale climate

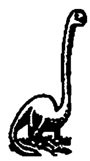


# Recent Results:
# Small Mammal/Keystone species

**Shortgrass Steppe Research on Black-Tailed Prairie Dogs (*Cynomys ludovicianus*)**




New!



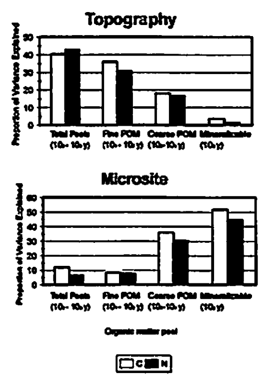
# Recent Results:
# Small Mammal/Keystone species

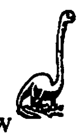
- Prairie dog towns are associated with specific landscape positions and soil types
- Drainages are important dispersal corridors
- Ongoing dispersal has a strong impact on genetic structure
- Burrow construction has more influence on fauna and flora than does grazing by prairie dogs

# Recent Results:
# Small Mammal/Keystone species

- A synthesis (Stapp 1998) suggests that there are insufficient data at present to show that prairie dogs have clear effects on the resident fauna of the shortgrass steppe.

## Recent Results:Biogeochemistry



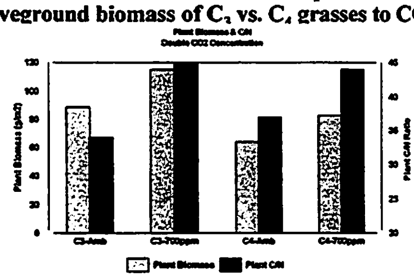



Topography controls slow pools of soil organic matter; microsite controls the fast turnover pools (Burke et al. in press)

## Climatic Variability:Increases in $CO_2$

**Mosier, Morgan, et al.**

- **Doubling of $CO_2$ enhanced aboveground NPP by 30%**
- **No differences were detected in the responsiveness of aboveground biomass of $C_3$ vs. $C_4$ grasses to $CO_2$ enric**




## Recent Publications supported by LTER

| | 1996 | 1997 | 1998 | 1999 | In press | Submitted |
|---|---|---|---|---|---|---|
| Journal Articles | 29 | 33 | 48 | 8 | 22 | ~18 |
| Chapters | 10 | 8 | 4 | 3 | 17 | (with in press) |
| Theses/Dissertations | 2 | 1 | 3 | 7 | | |

# Synthesis and Cross-Site Activities

- Cross-site grazing/exclosure
- Cross-site project with Argentina on NPP/decomposition
- Cross-site simulation analysis (Century/RAMS/TM/GEM)
  - Network office and San Diego Computer Center (Pielke et al)
- Cross-site project on role of cactus (Israel)
- Cross-site ant study (Wiens et al)
- SGS-Sevilleta transect work
  - Minnick/Coffin/Lauenroth
- SGS-Konza transect work
  - EPA grassland transect scaling study: Van Horne and Wiens
  - two new graduate student projects (McCulley and Bradford)

# Synthesis and Cross-Site Activities

- New SGS book in progress
  - Ecology of the Shortgrass Steppe: Perspe... from long-term research
  - 8 chapters submitted in draft form
  - 6 in outline form
  - Target date for chapters submitted to publisher: this December!

# Synthesis, Network, and Cross-Site Activities

- Regional analysis project comparing grasslands to agroecosystems in US and Argentina
- N-S transect study across grasslands on N retention (5 sites, Barrett)
- Effects of plant functional types on soils in semiarid systems (3 sites, Gill)

# Synthesis, Network, and Cross-Site Activities

- Modeling as an important synthesis activity
  - Century,
  - Steppe, Steppe-Century
  - Rams, Rams-Century, Rams-GEM
- Network participation and leadership:
  - Executive Committee (Burke)
  - Data Management Coordination Committee (Wasser)

# Synthesis Products, 1996-1999 Examples

- Controls over trace gas fluxes in grasslands
  - Mosier et al. 1996, 1997, 1998, 1999
- Transient responses of shortgrass steppe to climate change, Coffin and Lauenroth 1996
- Effects of prairie dogs on shortgrass steppe ecosystems, Stapp 1998
- Effects of grazing on fauna and flora of the shortgrass steppe: Milchunas et al. 1998
- Plant-soil interactions in grasslands: Burke et al. 1998

# Synthesis Products, 1996-1999 Examples

- Many regional papers, controls over ecosystem structure and function in grasslands:
  - Epstein et al. 1996, 1997, 1998
  - Burke et al. 1997
  - Lauenroth et al. submitted
  - Murphy et al. submitted
- Inter- and intraannual variability of ecosystem processes in shortgrass steppe
  - Kelly et al submitted
- Pedogenic characterization of the shortgrass steppe
  - Blecker et al. 1998

## Synthesis Productions, 1996-1999

- Issues in Ecology: Central North American Grasslands (in prep, Lauenroth et al).

## Graduate students:

- Many graduate students are working in association with the current LTER!
- Since 1996, LTER has supported 20-25 students
  - Via tuition, stipend, field support, lab support

## Research Experience for Undergraduates

- Since 1996, the LTER and associated projects have supported 12 REU students and 3 independent student projects:
  - Two papers have been published with undergraduates as authors/coauthors
  - Several others are in preparation for publication

## Progress in Education

- We receive Schoolyard LTER funding for educating K-12 about ecological research and about LTER
  - Moore, through Univ. Northern Colorado

## Progress in Data Management

- We have improved our data management system dramatically since 1996:
  - From asci to relational database
  - Relational database-web accessible via ORACLE
  - Relational database-web accessible via Access and Microsoft Visual Interdev
  - Dramatic increase in online datasets
  - Initiation of interactive GIS-data management
  - Initiation of GIS-data management system with site management data sets, interacting with Agricultural Research Service and the US Forest Service

## Overview of the day, agenda etc

- Monday, July 12th
  - 9:00 Welcome and Comments:
    - Dr. Jud Harper, Vice President For Research, CSU
    - Dr. Arvin Mosier, for the USDA-Agricultural Research Service Central Plains Experimental Range, Rangeland Research Unit
    - Steve Curry, for the Pawnee National Grasslands, USFS
  - 9:30 Introduction to the SGS LTER – Indy Burke
  - 10:30 Break and Questions

## Rest of Today:

- 11:00 Atmosphere – Ecosystem Interactions
  - Dr. Gene Kelly: paleoclimate and paleopedology
  - Dr. Roger Pielke: atmosphere-ecosystem interactions
  - Dr. Bill Parton: long term data analysis and modeling (?)
  - 12:00 Lunch in the cottonwoods
  - Brandon Bestelmeyer. Bob Schooley. invertebrates in the sgs
- 1:00 Grazing and small mammal herbivory
  - Dr. Daniel Milchunas
  - Dr. Jim Detling

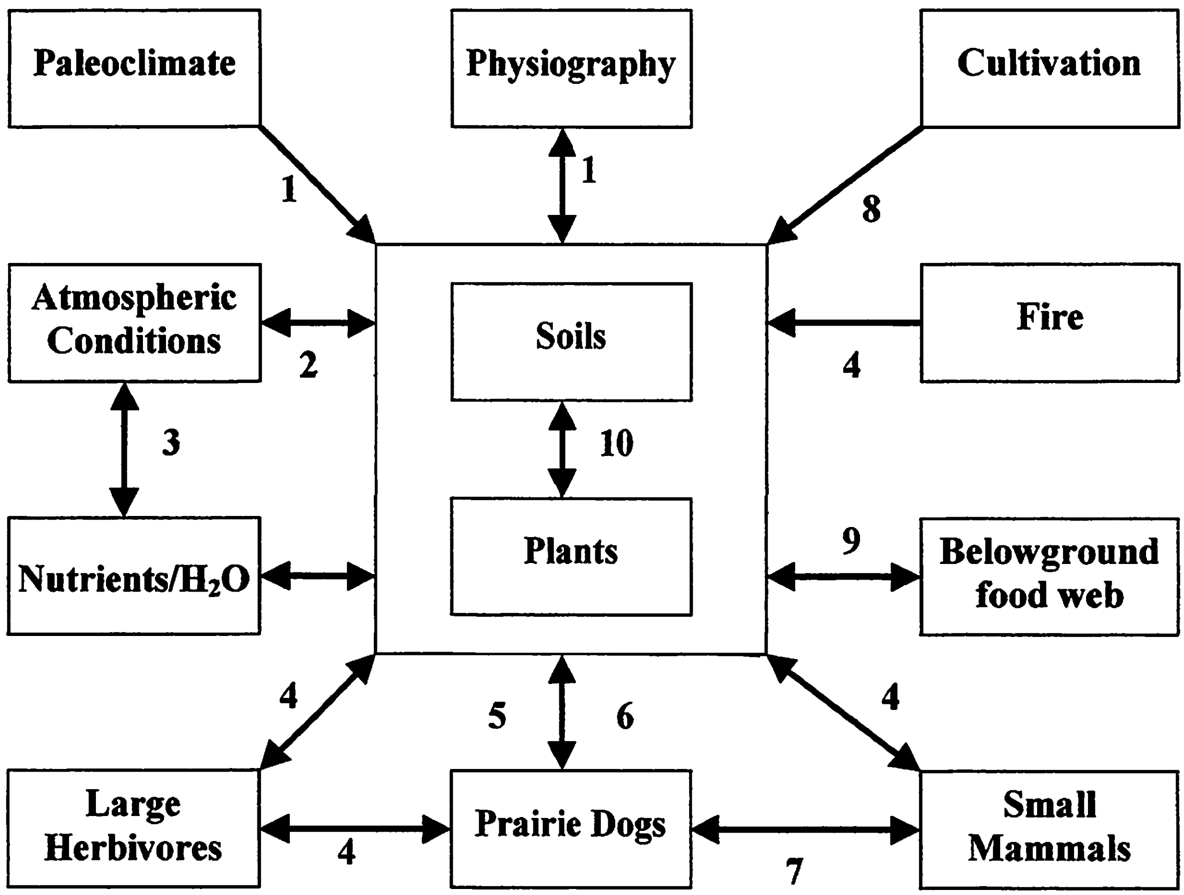
## Rest of Today

- 2:00 Enhanced $CO_2$ Experiment
  - Dr. Arvin Mosier
  - Dr. Dr. Dan LeCain
  - Dr. Dan Milchunas
- 3:00 Prairie Dogs
  - Dr. Bea Van Horne
  - Jeanine Junnell.
  - Dr. Jim Detling
  - Dr. Paul Stapp
- 4:30 – 6:00 poster session and meeting with graduate students and undergraduate students
- Cocktails when ready
- 6:00 - Barbecue

## Tuesday

- 7:30 – 8:30 Executive Session of Site Review Team over Breakfast
- 8:30 Data Management - Chris Wasser
- 9:00 Education and Outreach - Dr. John Moore/Indy Burke
- 9:15 Presentation/Discussion of our Leadership Structure/Administrative Connections (All)
- 10:00 Break
- 10:30 – 12:30 Site Review team meets with the key administrators:
  - 10:30 Jud Harper, VP for Research, CSU
  - 11:00 Denver Burns, USDA Forest Service, Director, Rocky Mountain Station
  - 11:30 Will Blackburn, USDA-ARS, Area Director
  - 12:00 Al Dyer, Dean, College of Natural Resources, Susan Stafford, Head, Dept Forest Sciences, and Dennis Child, Head, Dept of Rangeland Ecosystem Science
- 12:30 -Box lunch, and Site Review Team Report Writing Session

# Shortgrass Steppe LTER Research Activity Plan




1 Kelly

2 Pielke

3 Mosier

4 Milchunas

5 Van Horne

6 Detling

7 Stapp

8 Burke

9 Moore

10 Lauenroth

# LTER ATMOSPHERIC CONDITIONS

R.A. Pielke Sr.
Department of Atmospheric Science, Colorado State University, Ft. Collins, Colorado

## 1. Weather at the SGS LTER

The SGS LTER is located to the east of the Front Range of Colorado. As a result, in the cold season, the wind flow is predominately westerly and downslope off of the higher terrain to the west. This downslope flow results in generally dry and comparatively warm conditions, except when occasional polar high pressure systems move southward along the Front Range and turn the airflow upslope. During these events, periods of snow occur (or rain when the temperatures are warmer).

In the warm season, the heating of the landscape has a much larger effect on the wind flow and on precipitation. On a typical day, cool air draining from the elevated terrain of the Front Range and Cheyenne Ridge turn upslope towards this higher terrain as the land surface heats. If enough moisture is present in the atmosphere at low levels, thunderstorms develop over the Front Range and Cheyenne Ridge. These storms, most commonly, move eastward as a result of prevailing westerly winds at higher altitude in the troposphere. Short period rainfall, and often hail, result at the LTER site as these thunderstorms pass overhead.

Currently, we are examining the trends in wea--ther data at the LTER site, and elsewhere on the short grass steppe. Chase et al. (1999) examined the larger-scale trends since 1979, while Pielke et al. (1999) investigated the specific trends at available weather monitoring sites in eastern Colorado, including the CPER site within the SGS LTER. Stohlgren et al. (1998) studied the influence of irrigation on local summer weather along the Front Range. Figure 1a and 1b present the results for early spring minimum temperature, while Figure 1b hows the trends in growing season. Clearly evident in these figures (and in the other weather data we have analyzed) is the mixed trends in long-term averaged weather. Only the rapidly urbanizing Fort Collins site shows the large trends seen in the CPER data.

## 2. Atmosphere–Land Surface Interactions

Modeling experiments have been performed to investigate the feedback between the atmosphere, and land surface processes. Lu et al. (1999), for example, has used the RAMS-CENTURY coupled modeling system to investigate the relationship between weather and vegetation growth. That study has shown that the feedback between precipitation and above-ground vegetation growth results in wetter and cooler weather, than occurs if this feedback is excluded.

Eastman et al. (1999) have explored, using the RAMS-GEMTM modeling system, the influence of land-use change, and doubled $CO_2$ on the weather over a season. The experiments performed were (i) changing the central Great Plains from the current to an estimate of the natural landscape; (ii) doubling $CO_2$ in the radiation calculation in the RAMS model; and (iii) doubling $CO_2$ in the GEMTM component of the modeling system. The model simulation was for 210 days during the growing season in 1989. The control experiment (with the current landscape and $CO_2$ levels) was compared against observed weather and vegetation growth data. Figure 2 illustrates the spatial influence on the 210-day averaged maximum temperatures of each of the three effects shown above. Figure 3 illustrates the domain-averaged effect of the three model changes on maximum and minimum temperature, precipitation, and leaf area index. Both the change to the natural landscape and the biological effect of doubled $CO_2$ produced a cooling over the model domain.

## 3. Key Results

The key results from the study of the short grass steppe include the following:

1. *Anthropogenic landuse change exerts a major effect on both short- and long-term weather in the short grass steppe.*
2. *The effect of increased* $CO_2$ *on vegetation has an important rapid feedback to weather over the short grass steppe.*
3. *Since vegetation and soil dynamics interact with weather on short- and long-term time scales, it is inappropriate and, in error, to investigate climate without including vegetation and soil as integral components of the climate system.*

## 4. Compelling Questions for Current Research

1. What is the explanation for the mixed long-term weather patterns in the short grass steppe?
2. How can $CO_2$ chamber experiments and coupled atmosphere-land surface models be used

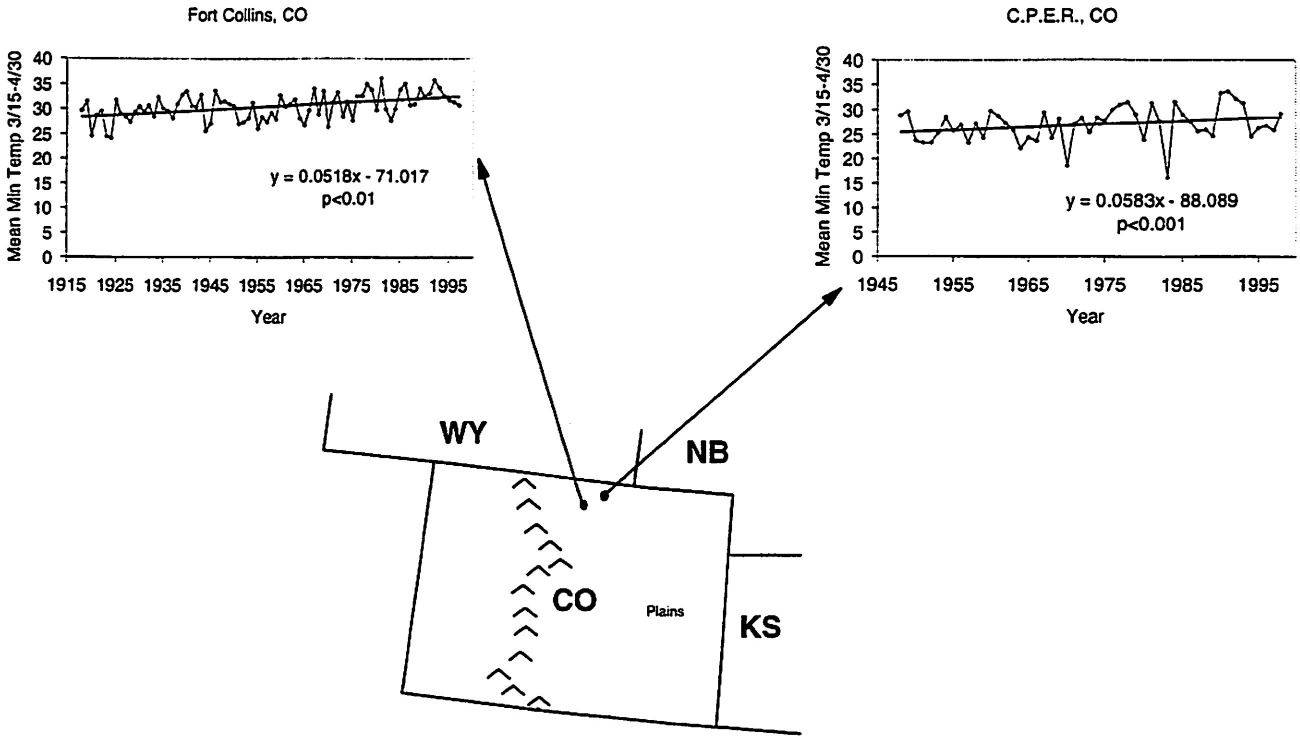



Figure 1: (a) Continued.

to improve the understanding of the potential climate consequences of enriched atmospheric concentrations of $CO_2$?

3. What role did grazing, fire, and prairie dog disturbance play within the climate system of the natural landscape? How important is current cattle grazing to the local climate?

## 5. References

Chase, T.N., R.A. Pielke, T.G.F. Kittel, R.R. Nemani, and S.W. Running, 1998: Simulated impacts of historical land cover changes on global climate. *Climate Dynamics*, accepted.

Eastman, J.L., M.B. Coughenour, and R.A. Pielke, 1999: The effects of $CO_2$ and landscape change using a coupled plant and meteorological model. *Global Change Biology*, submitted.

Lu, L., R.A. Pielke, G.E.Liston, W.J. Parton, D. Ojima, and M. Hartman, 1999: Implementation of a two-way interactive atmospheric and ecological model and its application to the central United States. *J. Climate*, submitted.

Pielke, R.A., T. Stohlgren, B. Parton, N. Doesken, L. Schell, J. Moeny, and K. Redmond, 1999: Mixed climate signals in eastern Colorado. In preparation.

Stohlgren, T.J., T.N. Chase, R.A. Pielke, T.G.F. Kittel, and J. Baron, 1998: Evidence that local land use practices influence regional climate and vegetation patterns in adjacent natural areas. *Global Change Biology*, 4, 495-504.

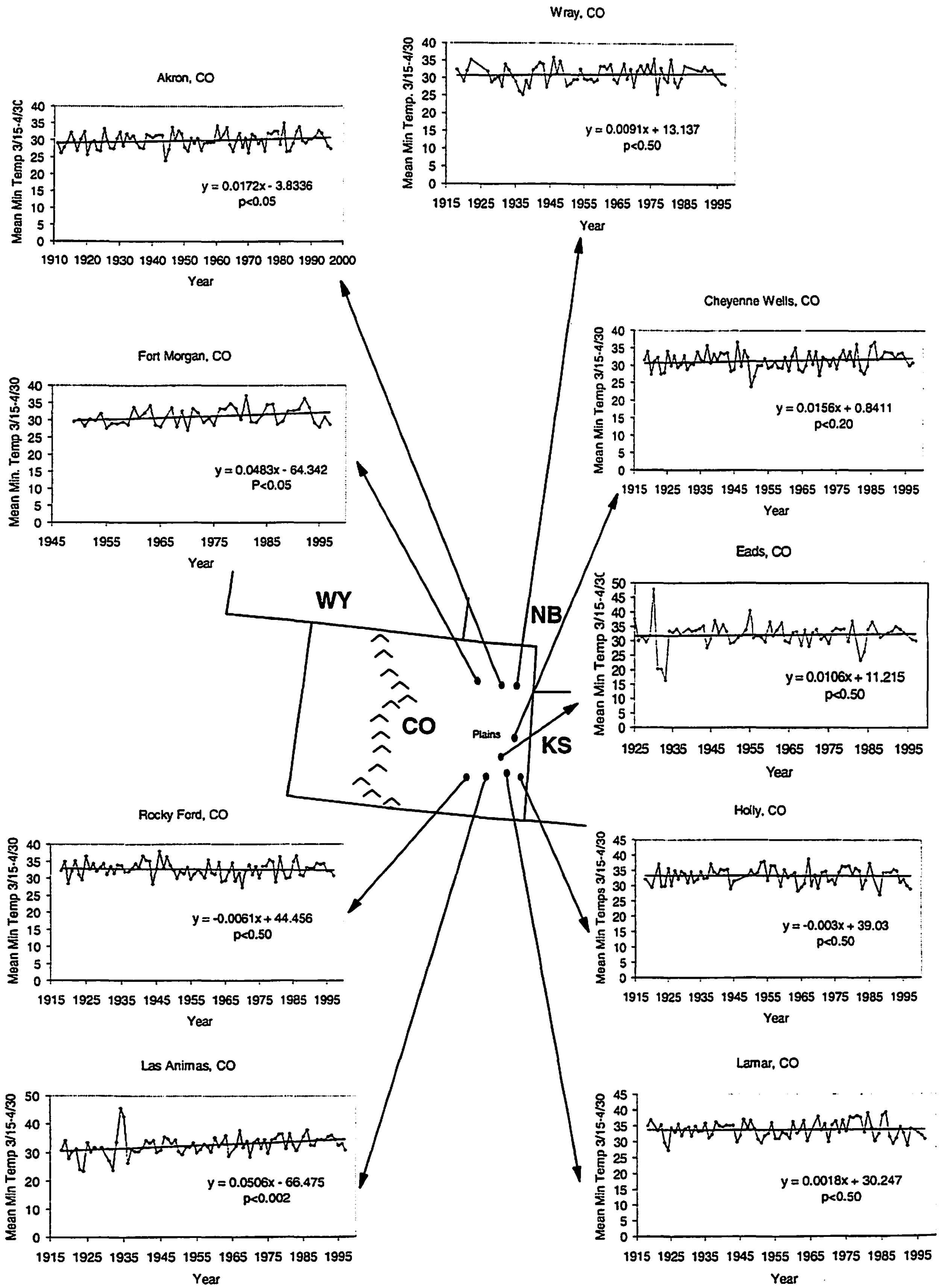



Figure 1: (a) Mean minimum temperatures for 15 March to 30 April for Colorado locations (from Pielke et al. 1999).

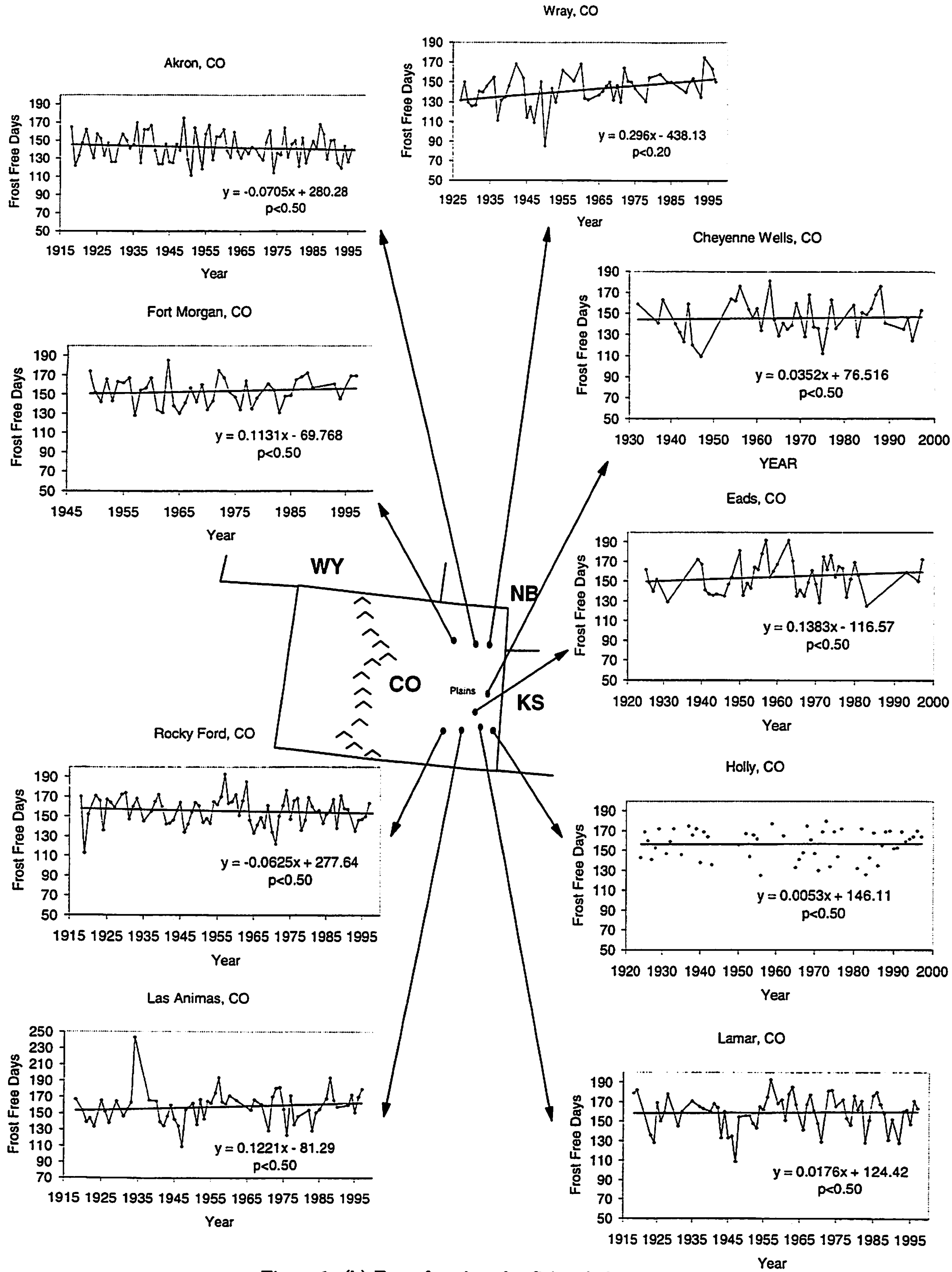



Figure 1: (b) Frost free days for Colorado locations.

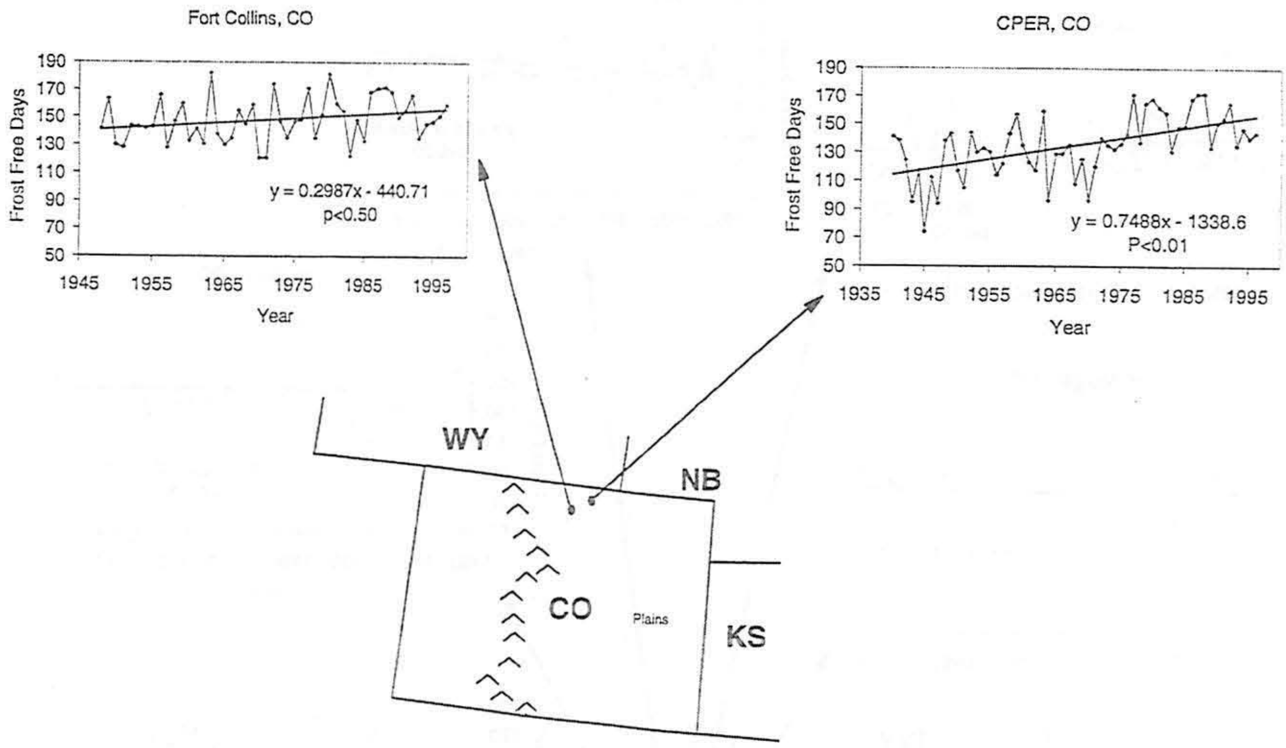



Figure 1: (b) Continued.

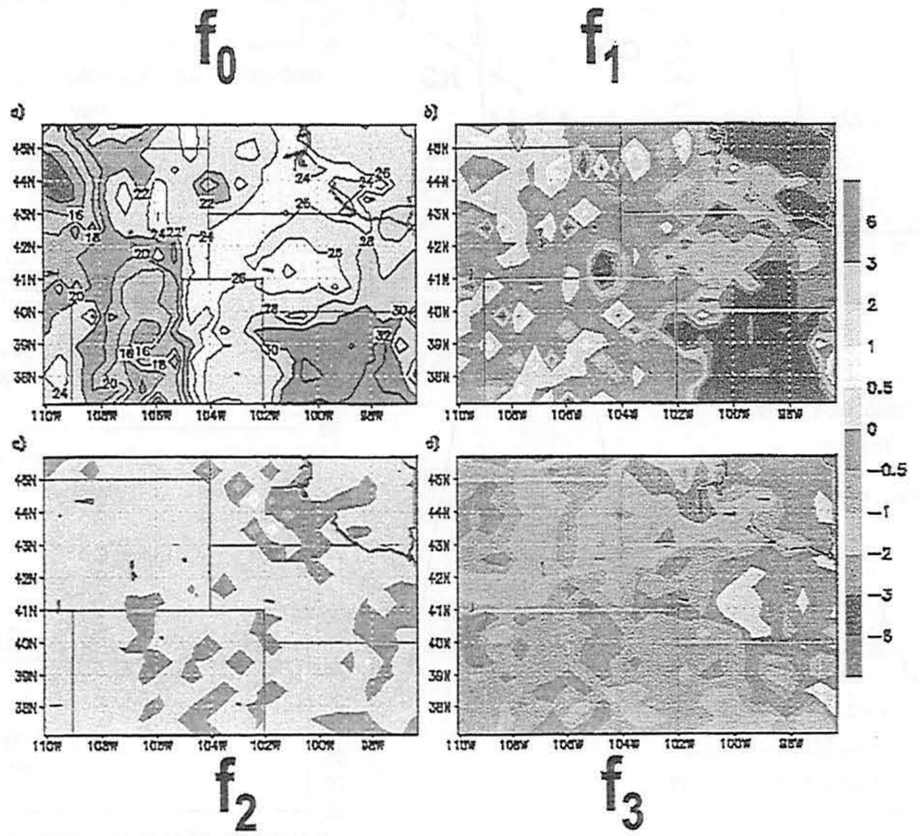



Figure 2: 210-day averaged maximum daily temperature where $f_0$ is the control experiment; $f_1$ is the change when the natural landscape is used; $f_2$ is the change when doubled $CO_2$ is specified in RAMS; and $f_3$ is when doubled $CO_2$ is used in GEMTM.

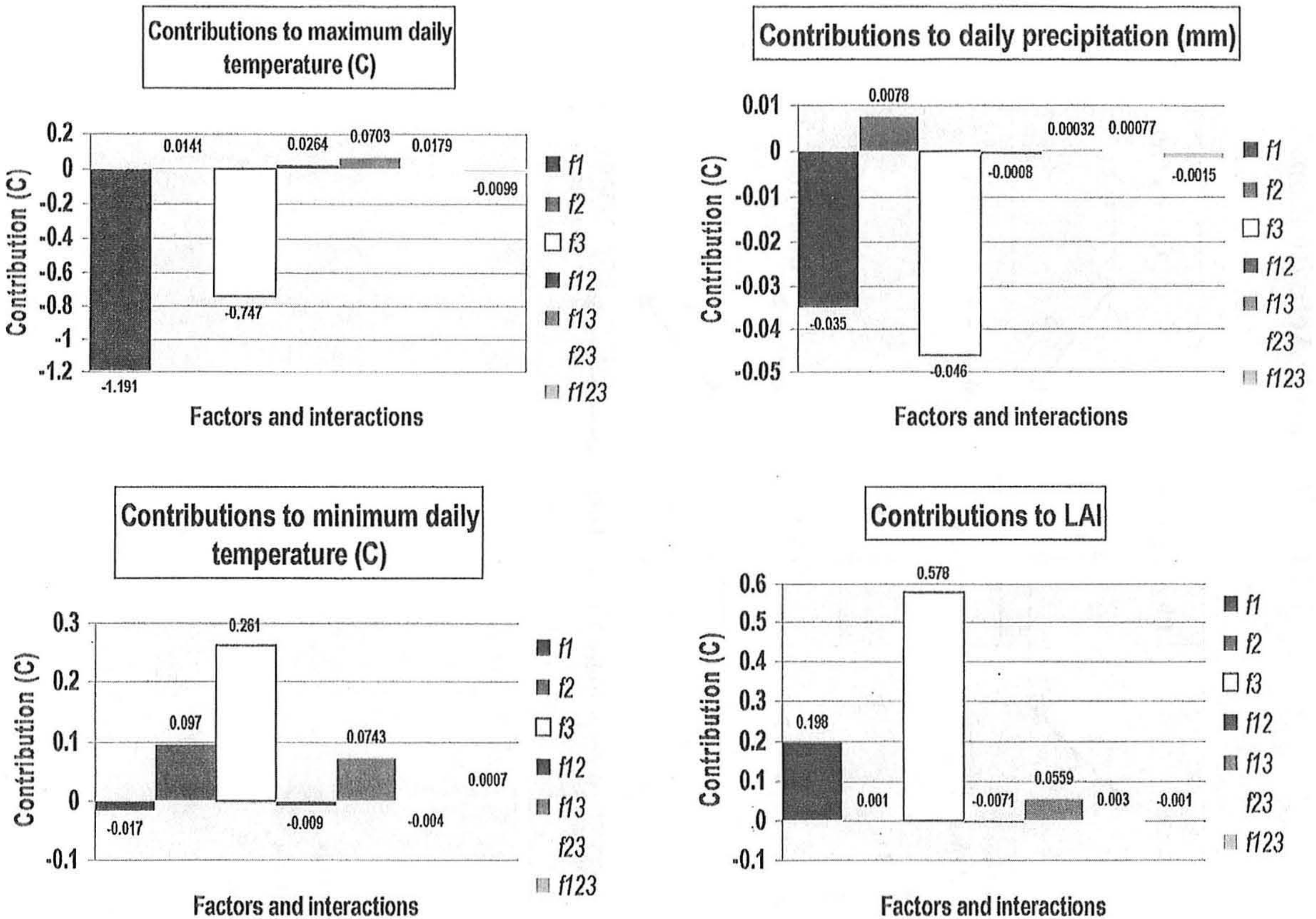
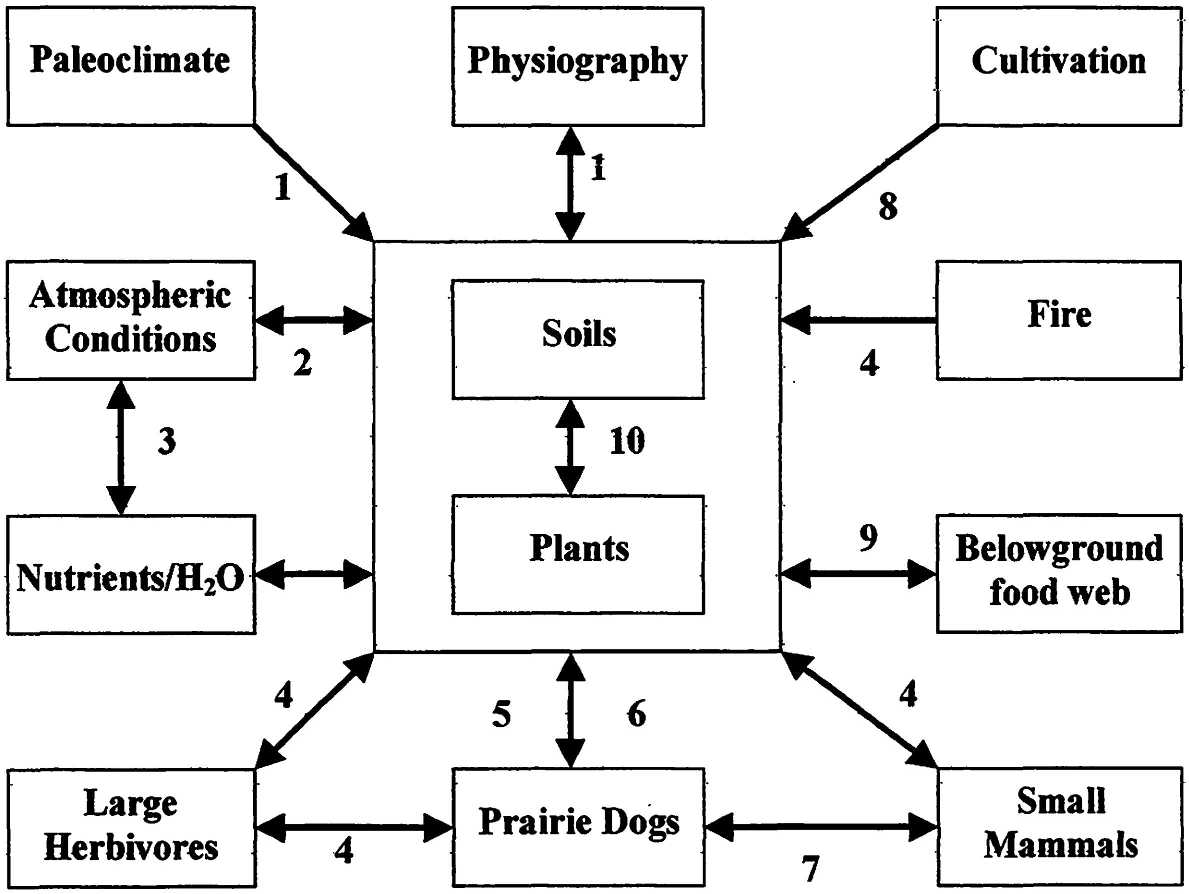



Figure 3: 210-day domain-average contributions to maximum daily temperature, daily minimum temperature, daily precipitation, and leaf area index for natural landscape (black bar), doubled $CO_2$ in RAMS (blue bar), doubled $CO_2$ in GEMTM (white bar), and interactions among the different effects (from Eastman et al. 1999).

# Shortgrass Steppe LTER Research Activity Plan




1 Kelly

2 Pielke

3 Mosier

4 Milchunas

5 Van Horne

6 Detling

7 Stapp

8 Burke

9 Moore

10 Lauenroth

## Physiography and Paleoclimatic Investigations

***Geology and Physiography of the Shortgrass Steppe***

The shortgrass steppe lies entirely within the boundary of the Great Plains physiographic province, a region characterized by its minimal topographic relief but containing areas of structural highs and lows. Much of northeastern Colorado lies within the latter, an area known as the Colorado Piedmont, which distinguishes itself from the remainder of the shortgrass steppe because of its unique geologic history.

The floor of the Colorado Piedmont consists of thousands of meters of interbedded sandstones and shales deposited following the uplift of the Rocky Mountains. Prior to the uplift, the mid-continent was covered by shallow seas. Uplift, which commenced during the late Cretaceous, forced the retreat of the sea. Streams flowing eastward from the mountains deposited sediment across a widening coastal plain. As uplift continued into the Tertiary, eroded sediments continued to accumulate, forming a depositional surface that extended across eastern Colorado, southern Wyoming, and western Nebraska and Kansas.

Then, in the late Tertiary, the existing river system began to cut into part of this vast surface. The prehistoric Arkansas and South Platte Rivers and their tributaries slowly excavated the Tertiary sedimentary deposits down to the older Cretaceous surface. The excavated area, known as the Colorado Piedmont, extends from the Colorado - Wyoming border south 700 km and from the Rocky Mountain front east 500 km. Consequently, the Colorado Piedmont is topographically lower than the High Plains to the north and east.

The South Platte River system continued its influence throughout the Pleistocene, eroding the Cretaceous deposits of the Piedmont to a low and gently rolling topography. Although the Piedmont itself was never glaciated, glacial outwash and alluvium from the Rocky Mountains were deposited in varying thicknesses. Periods of stream downcutting resulted in a series of well-established terraces along the Front Range. These terraces, which are quite distinct close to the mountain front, lose their topographic expression as they extend farther east into the Piedmont. A fluctuating Pleistocene climate resulted not only in alluvial deposition during interglacial and interstadial periods, but in the deposition of eolian materials as well during cool, arid intervals.

Key results to date

1) $^{14}C$ dates for CPER paleosols fit a model of Holocene landscape stability proposed in the geologic literature which includes: soil formation 12k-8k ybp, dune formation 8k-5k ybp, soil formation 5k-3k ybp, dune formation 3k-1.5k ybp, and soil formation 1.5k to present.

2) CPER surficial deposits are geologically "young", as indicated by the inappreciable mineral alternation of easily weatherable silicates such as muscovite and volcanic glass.

3) Grain-size frequency statistics indicate that early Holocene, mid Holocene and contemporary soils all formed in alluvial, as opposed to eolian, deposits.

4) The presence of argillic and calcic horizons is the result of eolian influx of clay and carbonate, and not the in situ weathering of soil minerals.

Compelling questions for current research

1) Geologic substrate and Pleistocene terrace expression differ in the eastern sector of the PNG. Is our current working model of Holocene landscape development, which defines our thinking regarding rate of soil development and biotic recovery, applicable?

2)The deposition and reworking of Holocene surficial deposits plays an important role in the current structure and function of the CPER portion of the SGS. Is the distribution of blue grama related to a driving variable other than surface soil texture in the eastern portion of the SGS, where the dominant geomorphic features are different?

### *Paleoclimate*

To date we have studied many sequences of buried soils in the western extreme of the Pawnee National Grasslands. These buried soils, or paleosols, record the vegetative and climatic conditions which prevailed during the last 10,000 years. These soils, which formed as the uppermost layer of the earth's surface, were buried by the widespread deposition of Holocene eolian, loess, and alluvial deposits. Buried soils are considered to contain information on pre-historic changes in climate and how the earth changed in response. This record provides perhaps the most reliable indication of how the earth may respond to future climate change. To establish vegetative and climatic histories, the stable carbon and oxygen isotopic compostion of various paleosol components were analyzed.

The $\delta^{13}C$ values of soil organic matter, $CaCO_3$ and phytolith is a function of the photosynthetic pathway of the prehistoric vegetative community. The $\delta^{18}O$ values of $CaCO_3$ is a function of air temperature and the source of the air masses which yielded precipitation during soil formation. This information, in addition to the size and orientation of paleosols, their radiocarbon age and other attributes have led to our working model of Holocene climate change and landscape evolution.

*Key results to date*

1) Higher proportions of $C_3$ vegetation persisted at the early Holocene. The concordance in the C isotopic signatures of soil organic matter and phytolith provide strong biological evidence of regionally cooler conditions.

2) C isotope concordance also appears during the mid-Holocene soil forming interval; C isotope values indicate an increase in the proportion of $C_4$ vegetation, which reflect regionally warmer climatic conditions than present.

3) Phytolith content used as a proxy for plant production, support a period of increased plant production since both the mid (5k-3k ybp) and early (10k-8k ybp) Holocene paleosols contain more than a two-fold increase in phytolith over their late Holocene (contemporary) counterparts.

*Compelling questions for current research:*

1) Is there a Pleistocene climate record preserved in soil carbonates along terrace chronosequences ?
2) Does the paleovegetation record indicate the dominance of blue grama in the mid Holocene, early Holocene and Pleistocene soil forming intervals?
3) How does the Pleistocene climatic record compare to other terrestrial records we have studied in the continental United States (east central Great Plains, Palouse, Wind River Basin)?

***Key References:***


Kelly, E.F., Marino, B.D, Yonker. (1993). The Stable Carbon Isotope Composition of Paleosols: An Application to the Holocene. *Climate Change in Continental Isotopic Records, American Geophysical Union. Geophysical Monograph 78:233-240.*

Blecker, S., Yonker, C.M., Olson, C.G. and Kelly, E.F. (1997). Indicators of Holocene Climate Variations: Pedogenic Characterization of Shortgrass Steppe Soils, Colorado. *Geoderma. 76:113-130.*

Kelly, E.F. Blecker, S., Yonker, C.M., Olson , E.E. Wohl, and L. Todd. (1998). Stable Isotope Composition of Soil Organic Matter and Phytoliths as Paleoenvironmental Indicators. *Geoderma. 82:59-81.*


***Researchers and Collaborators:***

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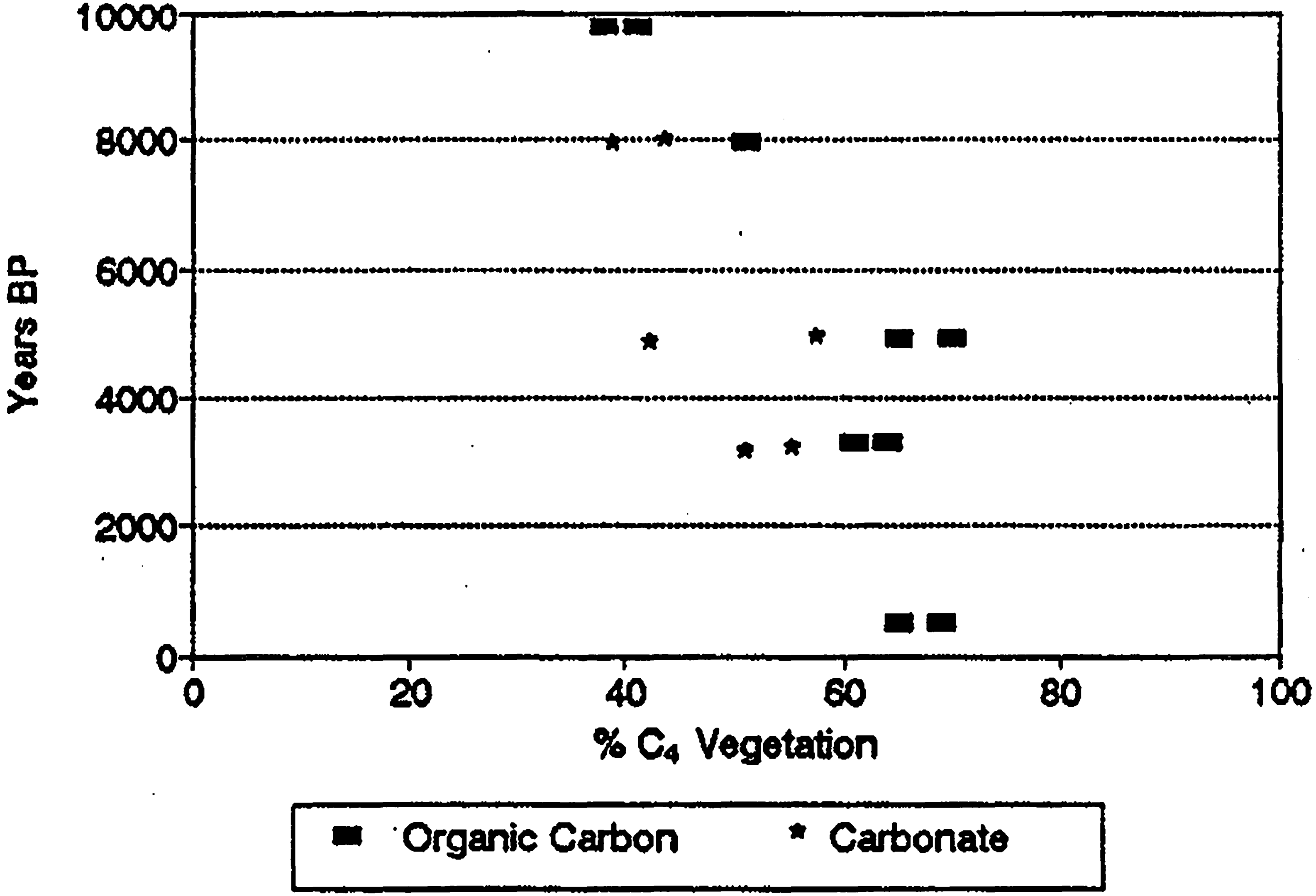
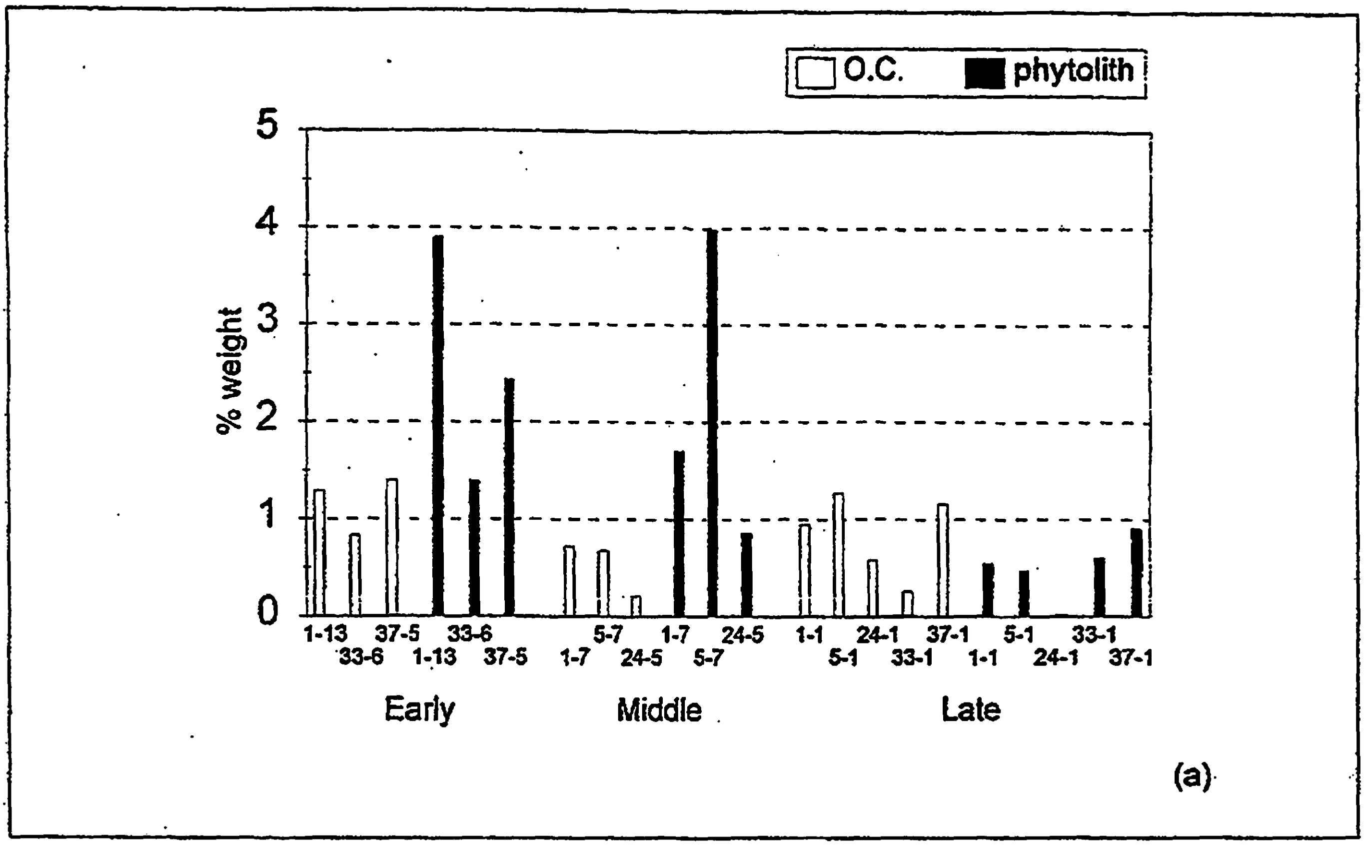
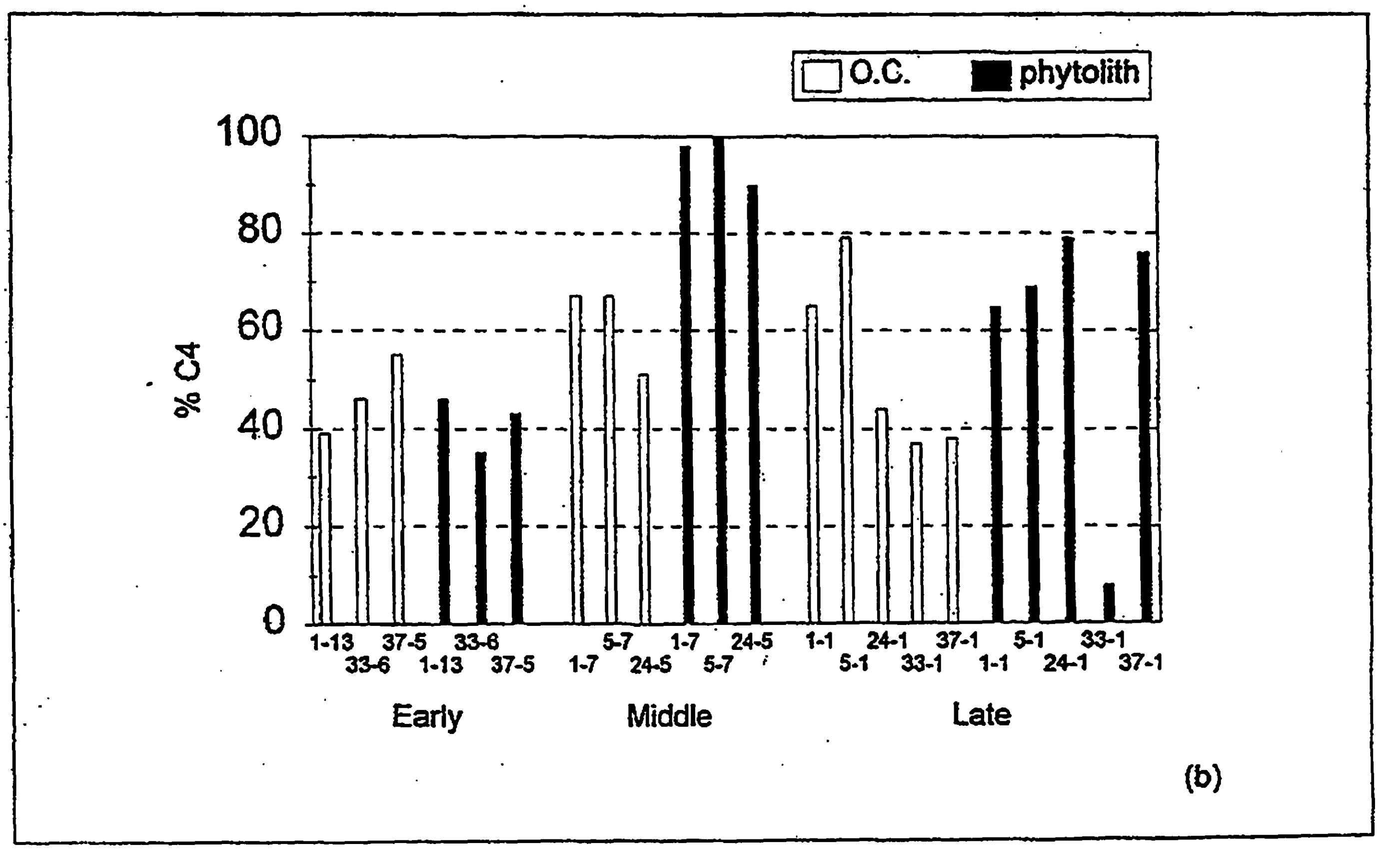
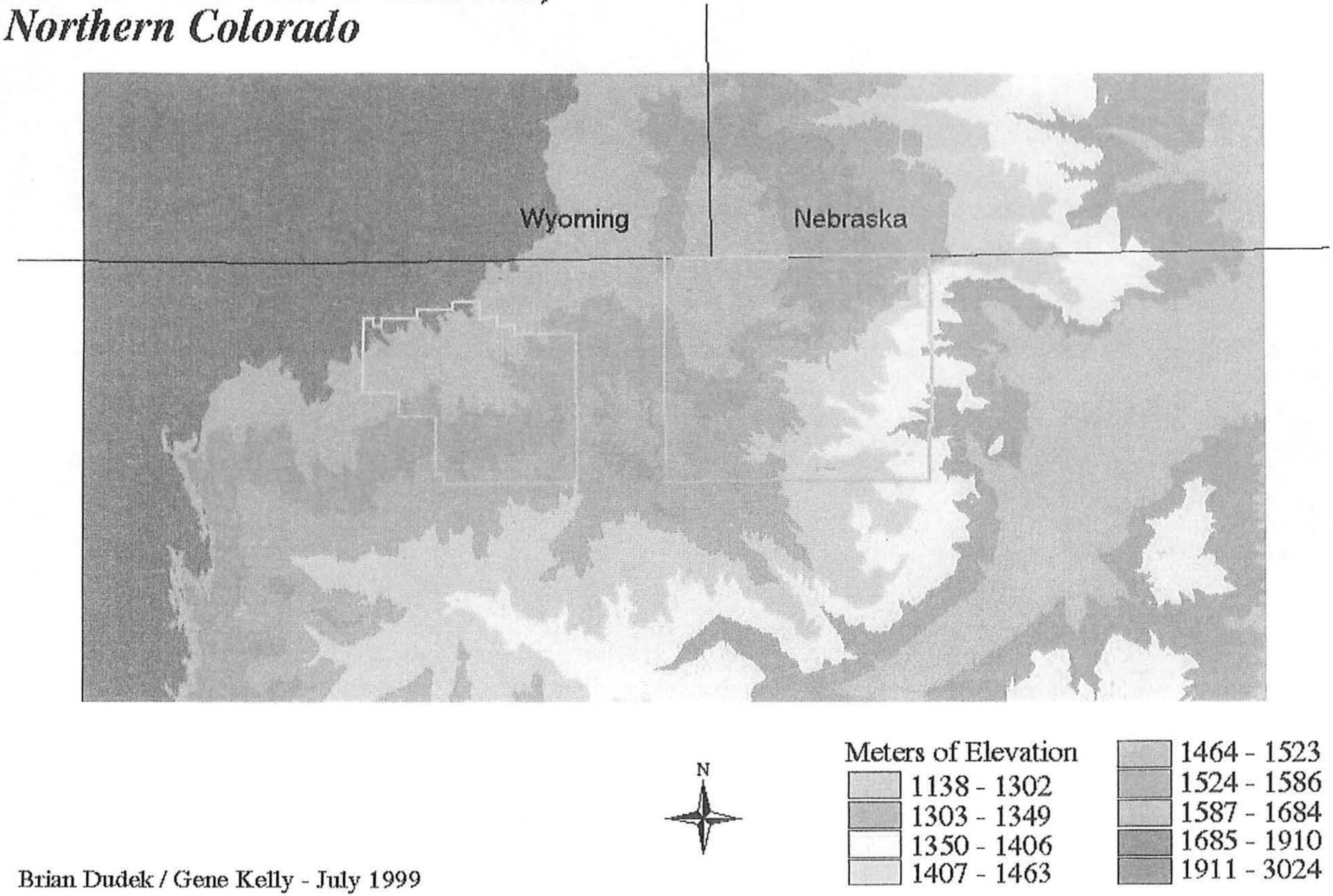
Caroline Yonker, Soil and Crop Sciences, CSU,
Susie Loadholt, Soil & Crop Sciences, CSU.
Elizabeth Sulzman, Soil & Crop Sciences, CSU
Rosemary Capo, Univ. of Pittsburg, PA
Michael Petersen, USDA-NRCS, Greeley, CO
Stan Glaum, USDA-NRCS, Salinas, KS
Carolyn Olson, USDA-NRCS, Lincoln, NE


Years BP
10000
8000
6000
4000
2000
0
0
20
40
60
80
100
% C4 Vegetation
Organic Carbon
Carbonate


O.C.
phytolith
% weight
0
1
2
3
4
5
1-13
33-6
37-5
1-13
33-6
37-5
1-7
5-7
24-5
1-7
5-7
24-5
1-1
5-1
24-1
33-1
37-1
1-1
5-1
24-1
33-1
37-1
Early
Middle
Late
(a)


O.C.
phytolith
% C4
0
20
40
60
80
100
1-13
33-6
37-5
1-13
33-6
37-5
1-7
5-7
24-5
1-7
5-7
24-5
1-1
5-1
24-1
33-1
37-1
1-1
5-1
24-1
33-1
37-1
Early
Middle
Late
(b)

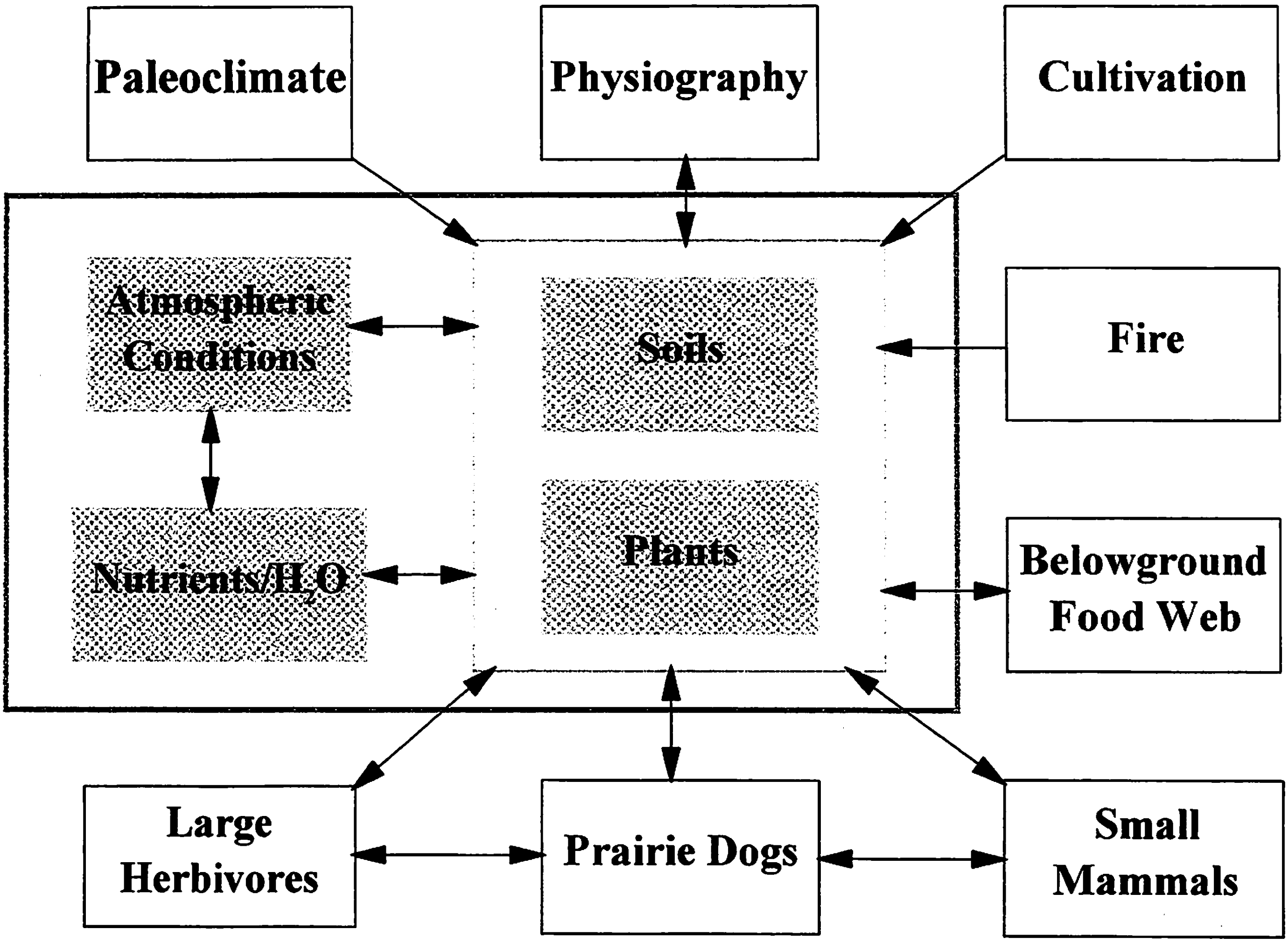
# *Elevation Zones of the Pawnee National Grasslands, Northern Colorado*




Brian Dudek / Gene Kelly - July 1999

# Climate Change and The Shortgrass Steppe


## William J. Parton

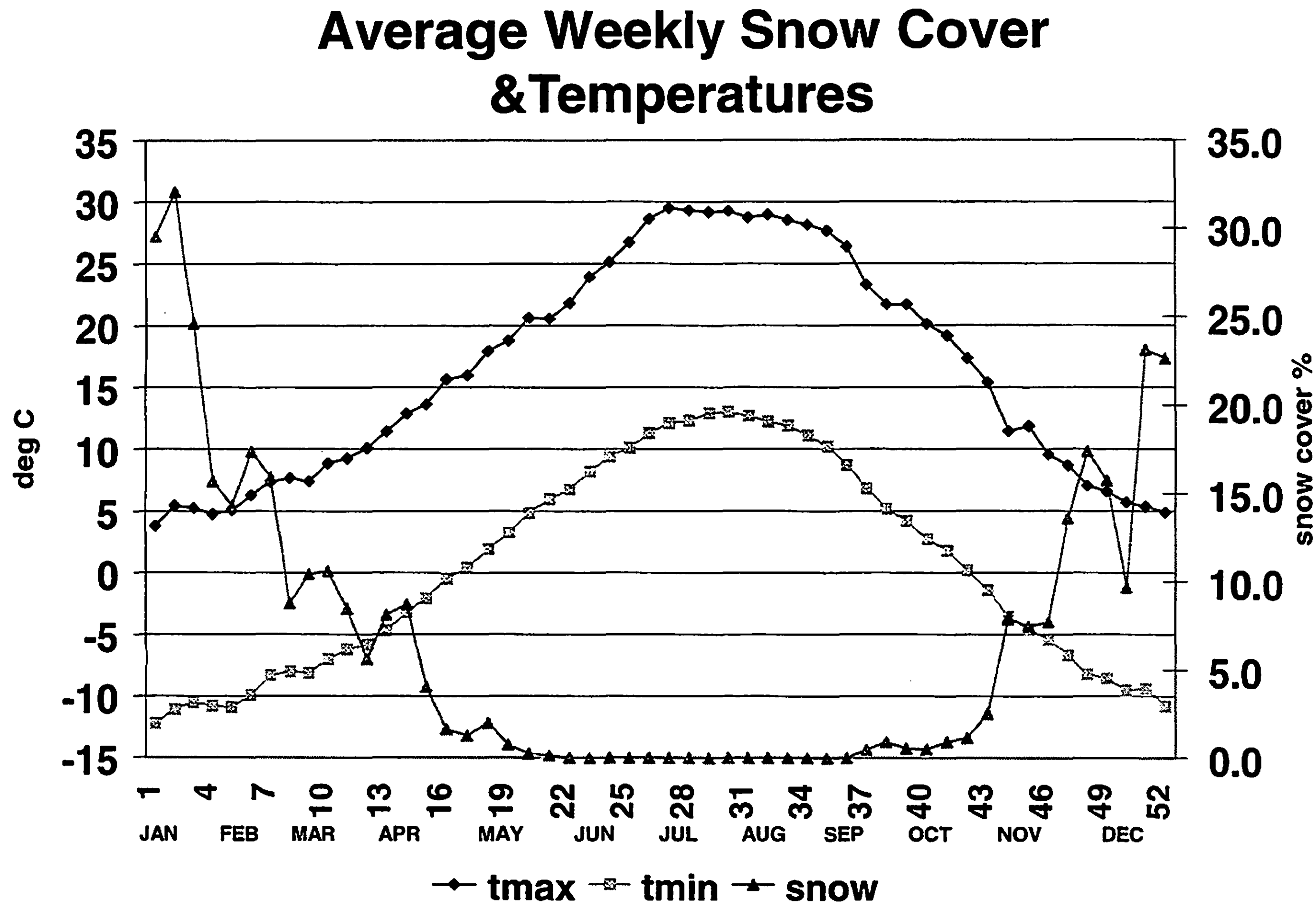
# OUTLINE

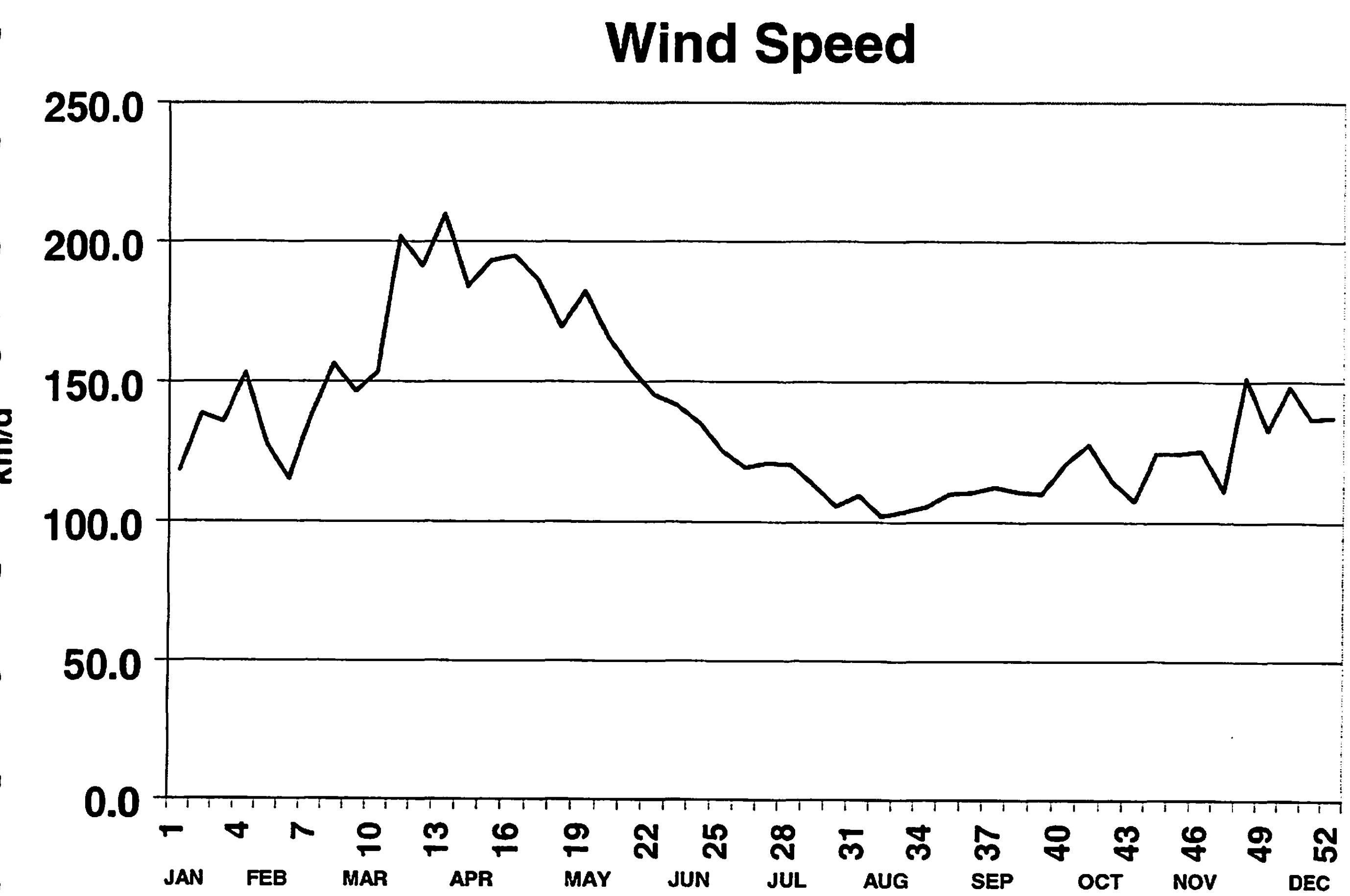
1. Climate Description
    - Max and Min T
    - Precipitation
    - Wind - direction and speed
    - Soil Water

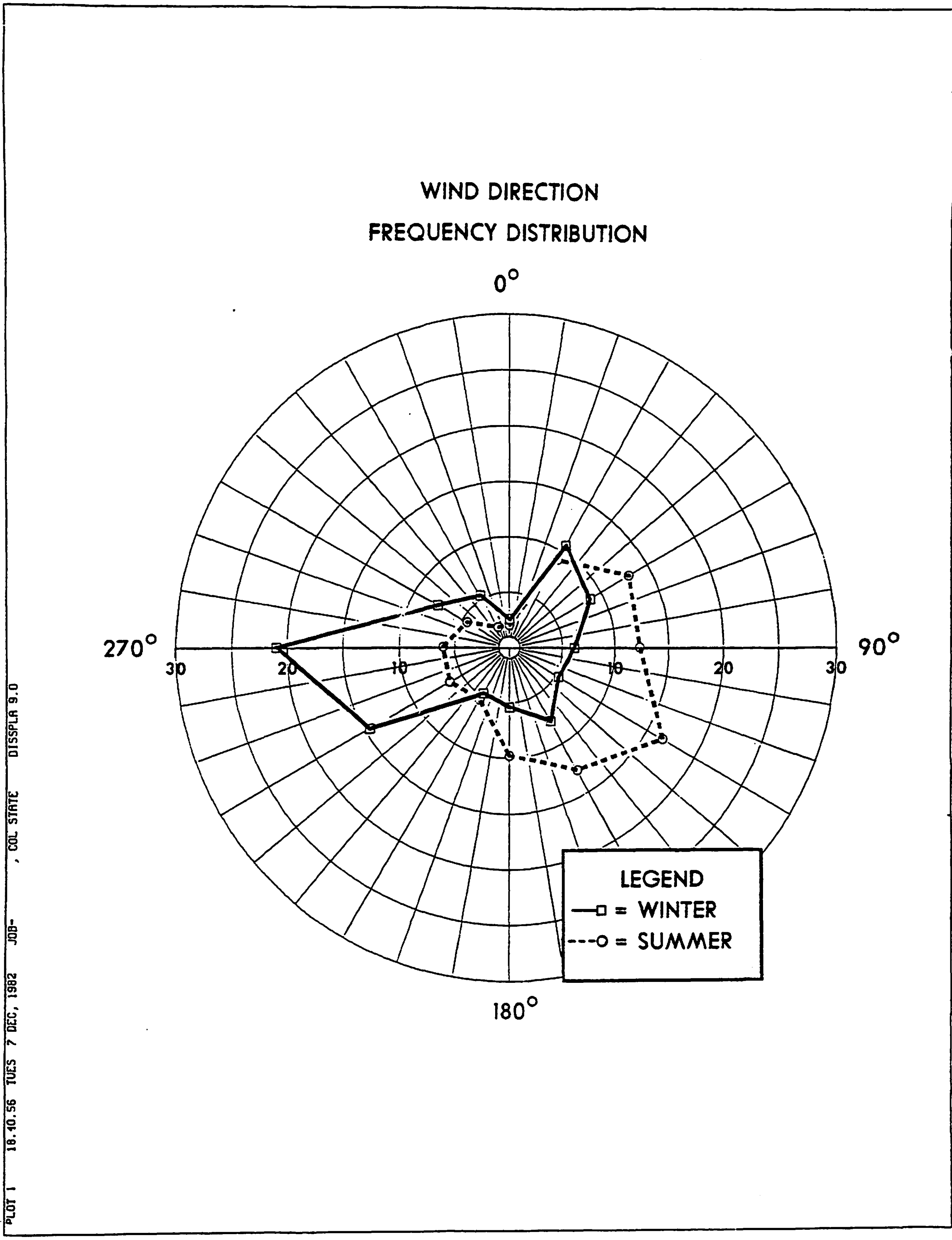
2. Climatic Trends
    - Max and Min T
    - Wind Speed
    - Snow Cover
    - Pan Evaporation

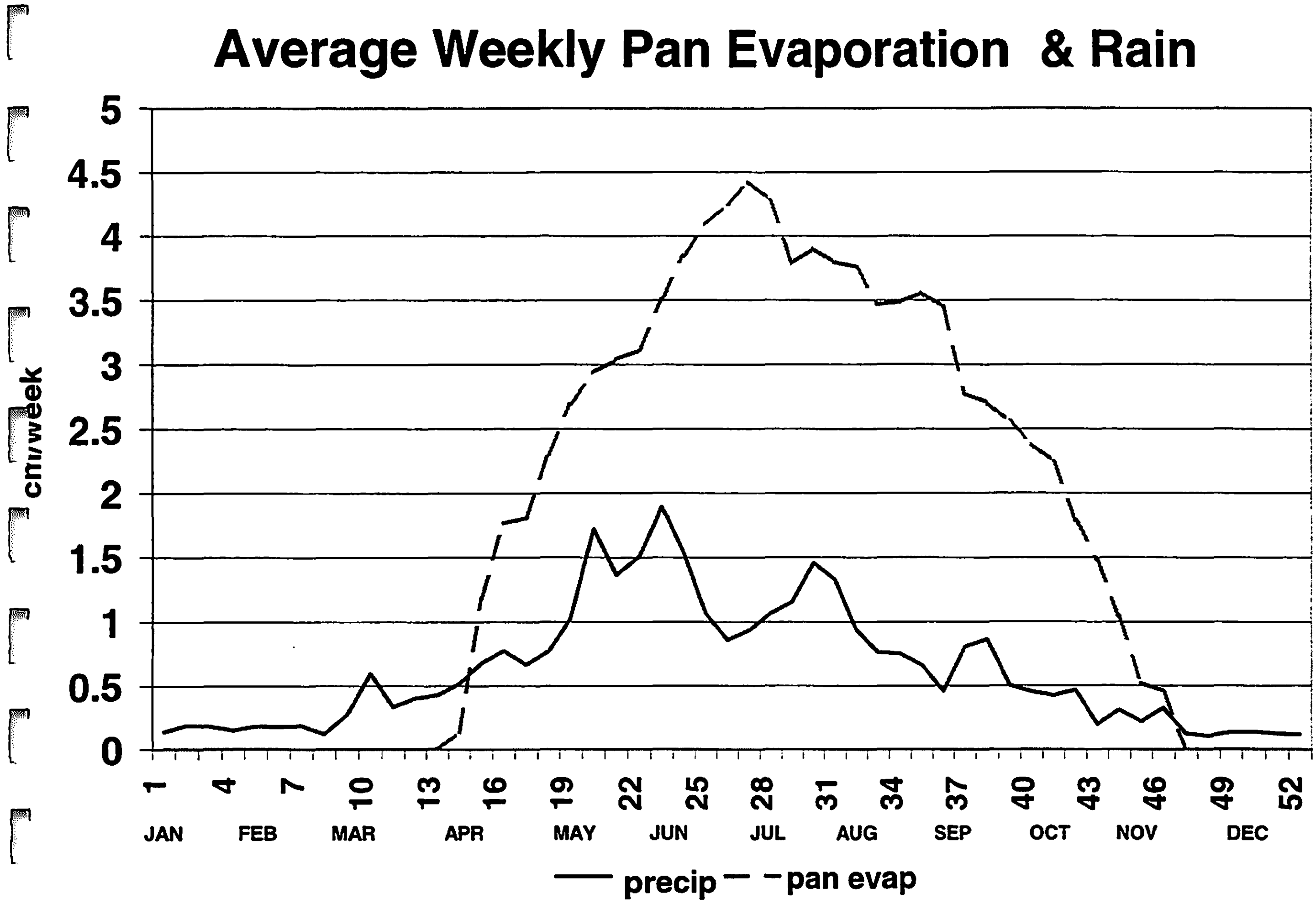
3. Cheyenne Weather
    - Pan Evaporation
    - Max and Min T
    - Wind Speed

4. Regional Pan Evaporation


Average Weekly Snow Cover &Temperatures
deg C
snow cover %
35
30
25
20
15
10
5
0
-5
-10
-15
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
tmax tmin snow


Wind Speed
km/d
250.0
200.0
150.0
100.0
50.0
0.0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC


WIND DIRECTION
FREQUENCY DISTRIBUTION
0°
90°
180°
270°
30
20
10
10
20
30
LEGEND
= WINTER
= SUMMER
PLOT 1 18.10.56 TUES 7 DEC, 1982 JOB- , COL STATE DISSPLA 9.0


Average Weekly Pan Evaporation & Rain
cm/week
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
JAN
FEB
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MAY
JUN
JUL
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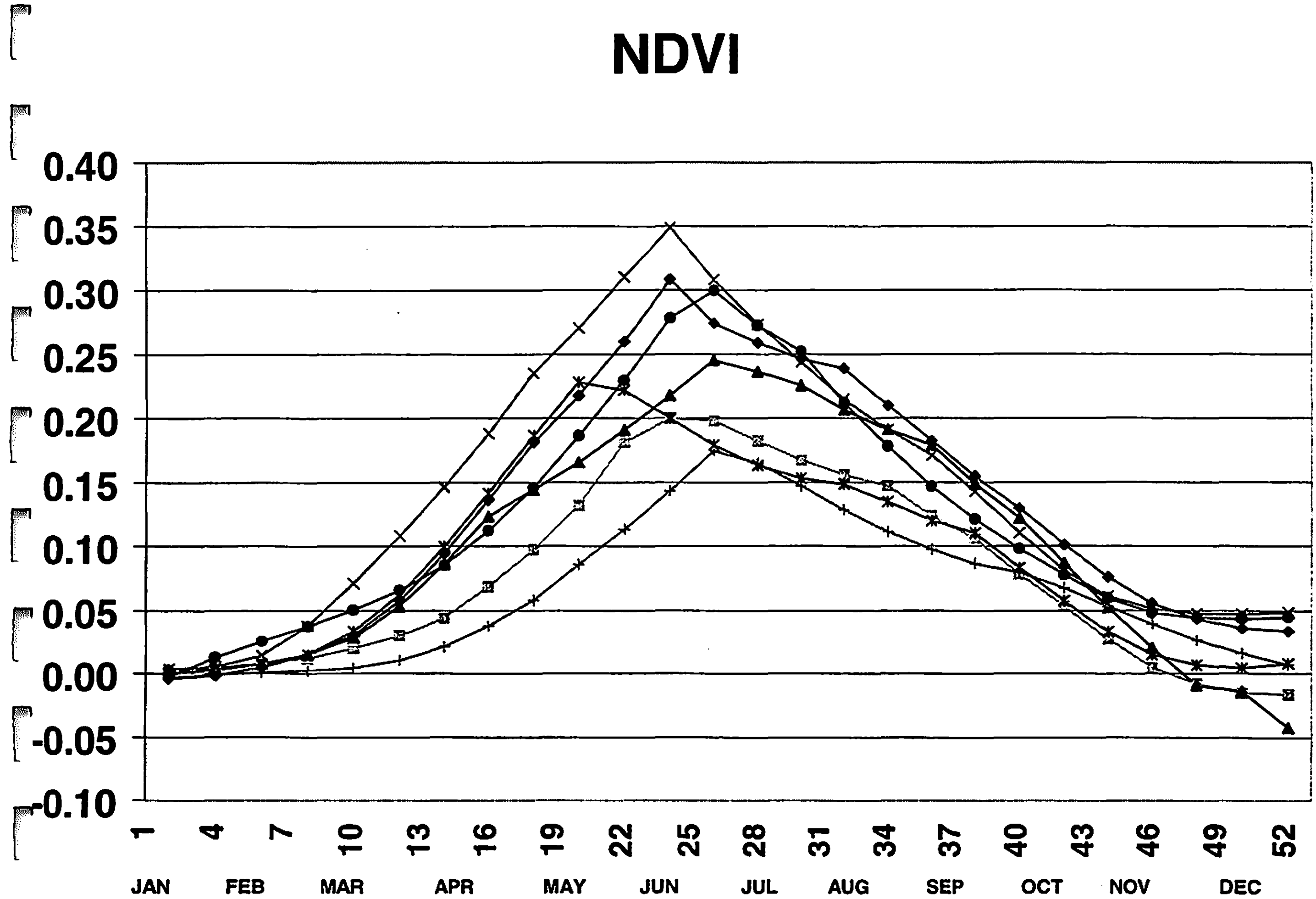
SEP
OCT
NOV
DEC
precip
pan evap


NDVI
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
JAN
FEB
MAR
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DEC

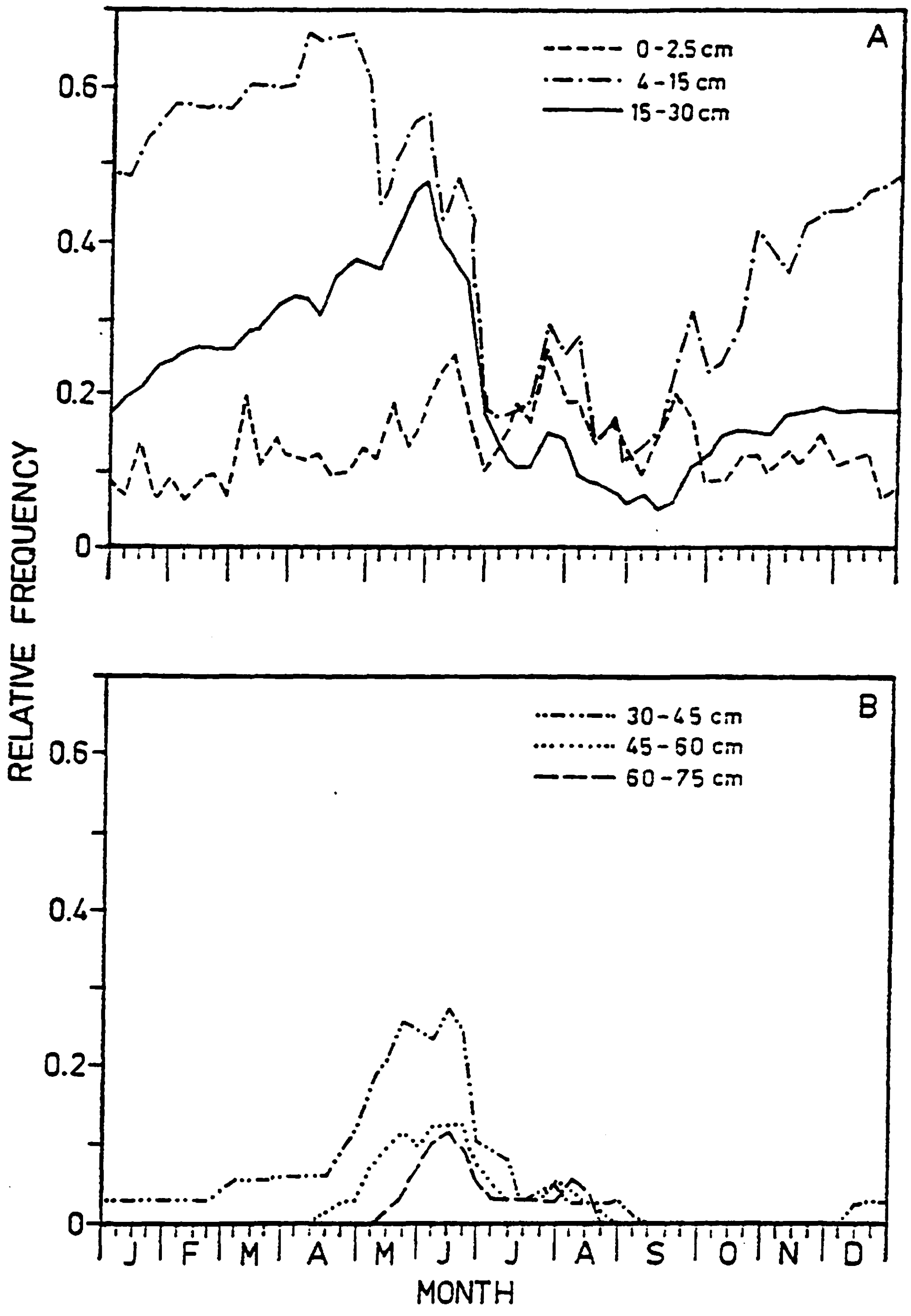
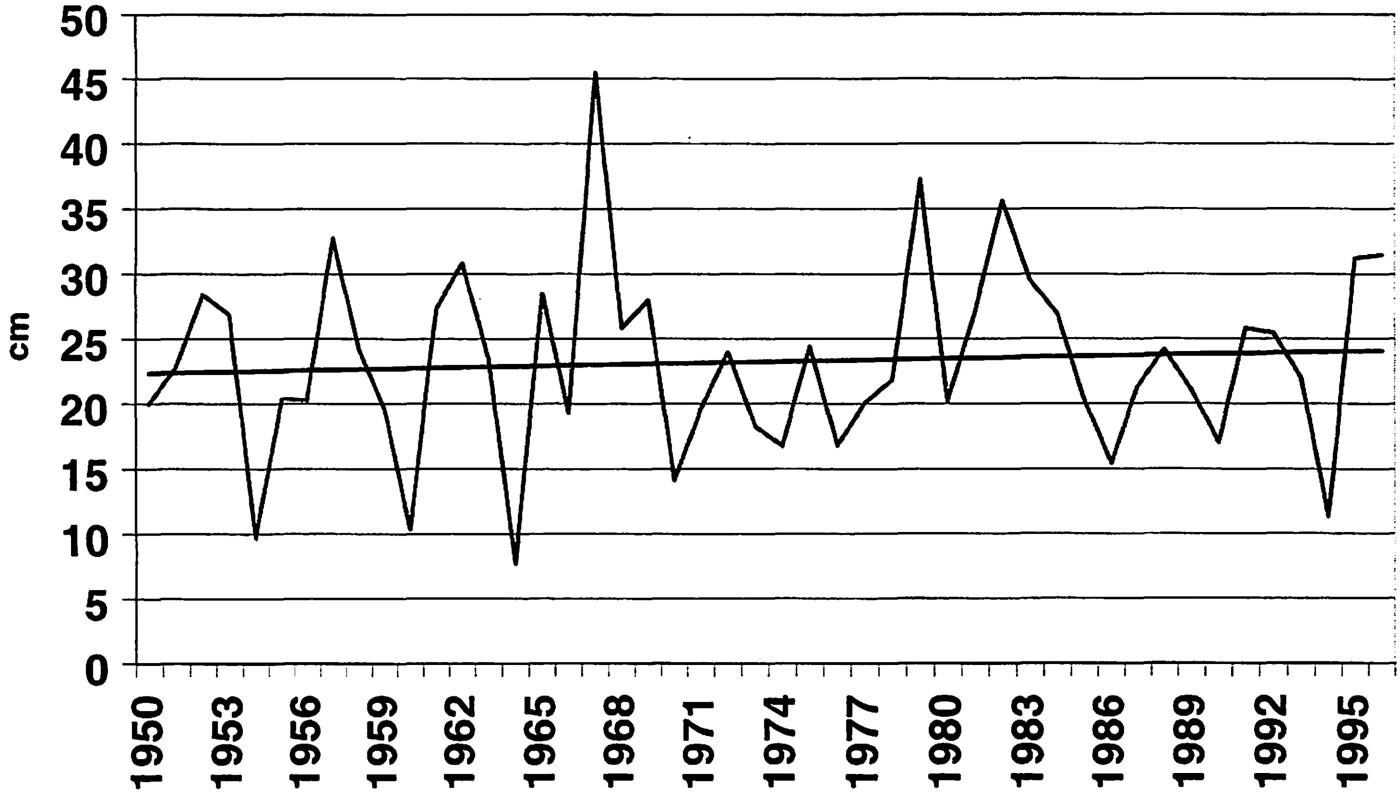
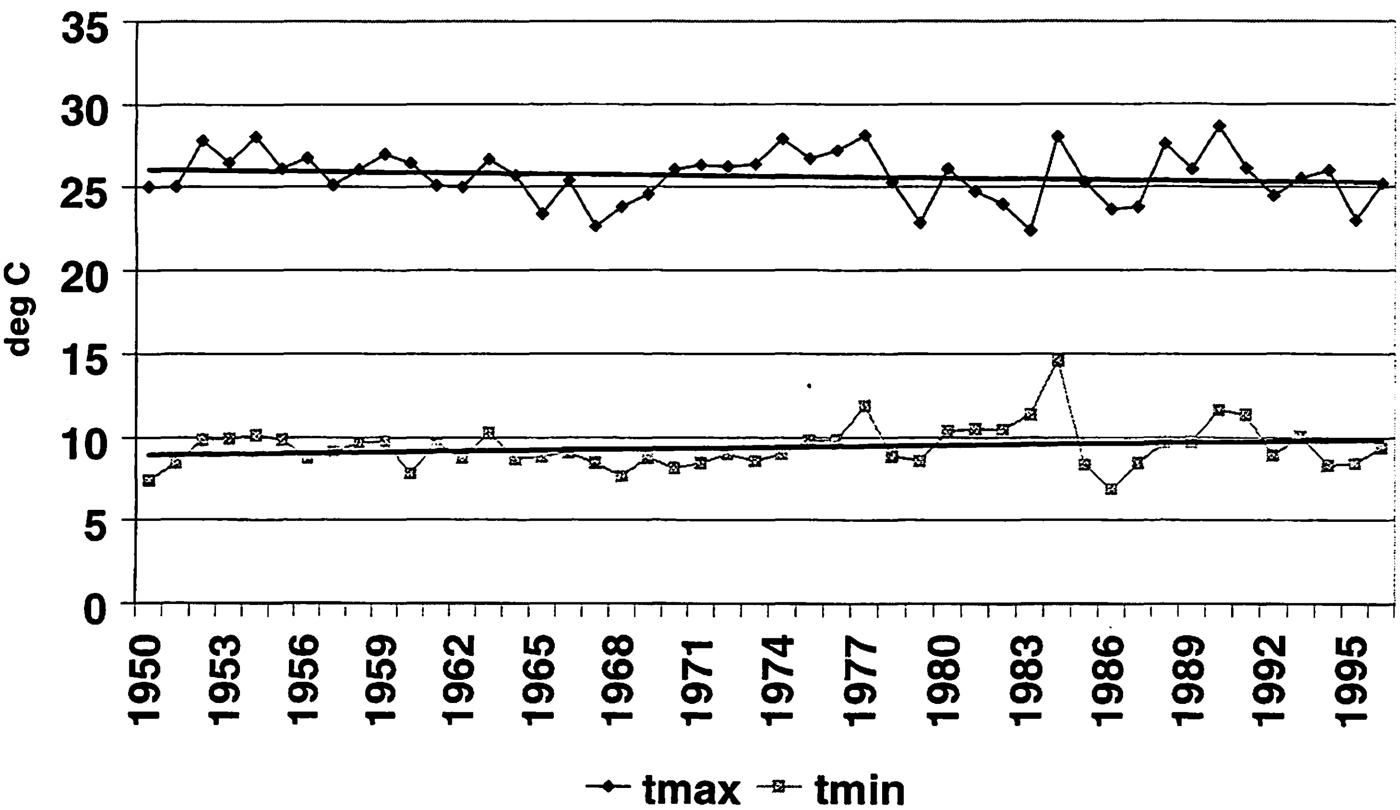



FIG. 5. Frequency of occurrence of soil water potential $>-1.0$ MPa through time for different soil depth layers in the shortgrass steppe of northcentral Colorado. The frequency was calculated as the number of days in each calendar week that had soil water potential $>-1.0$ MPa, out of 231 d (33 yr·7 d/wk). Soil water potential between 0 and $-1.0$ MPa indicates that water is available for plants. (A) for upper soil layers and (B) for lower soil layers.

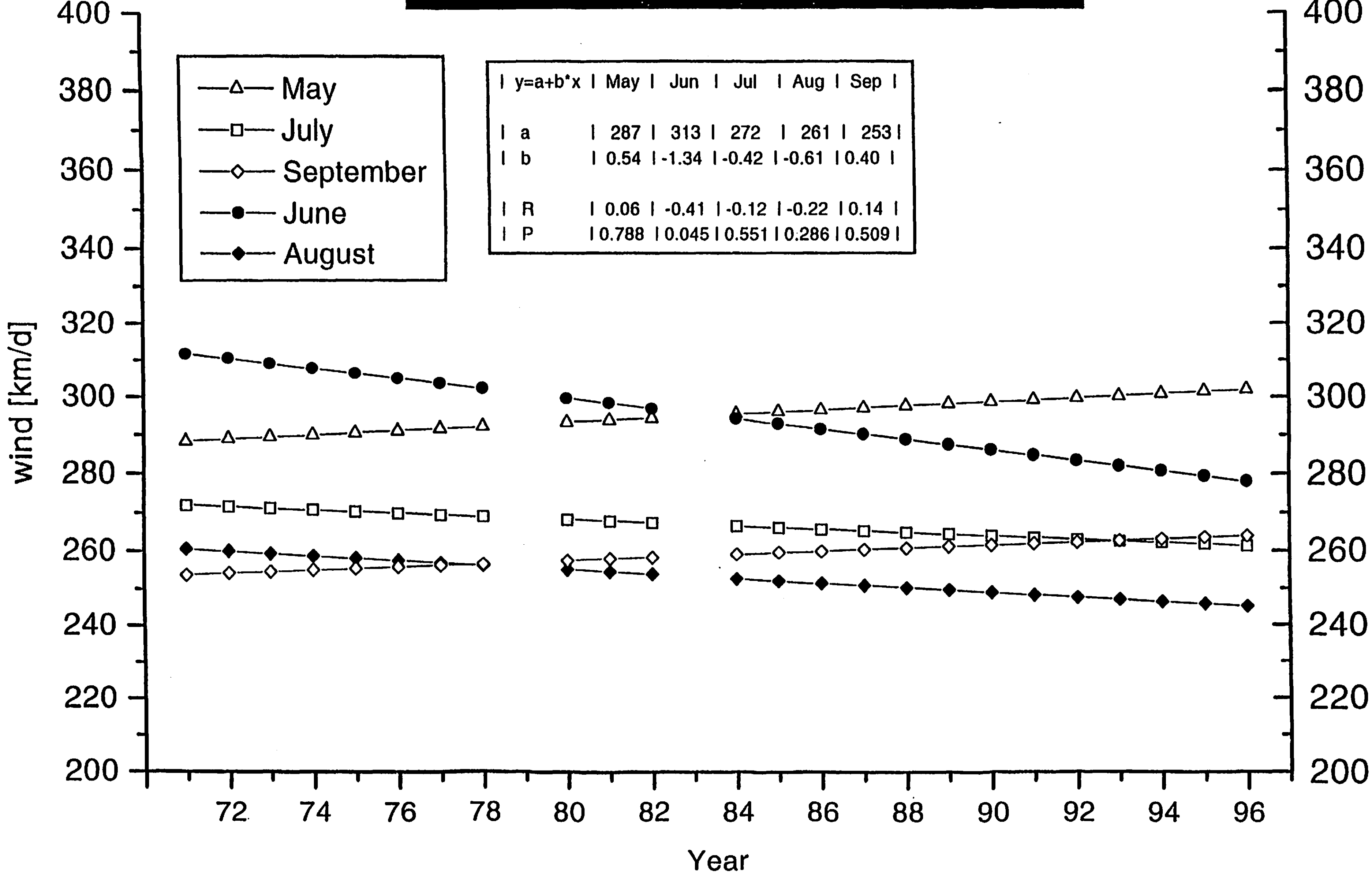
# Precipitation



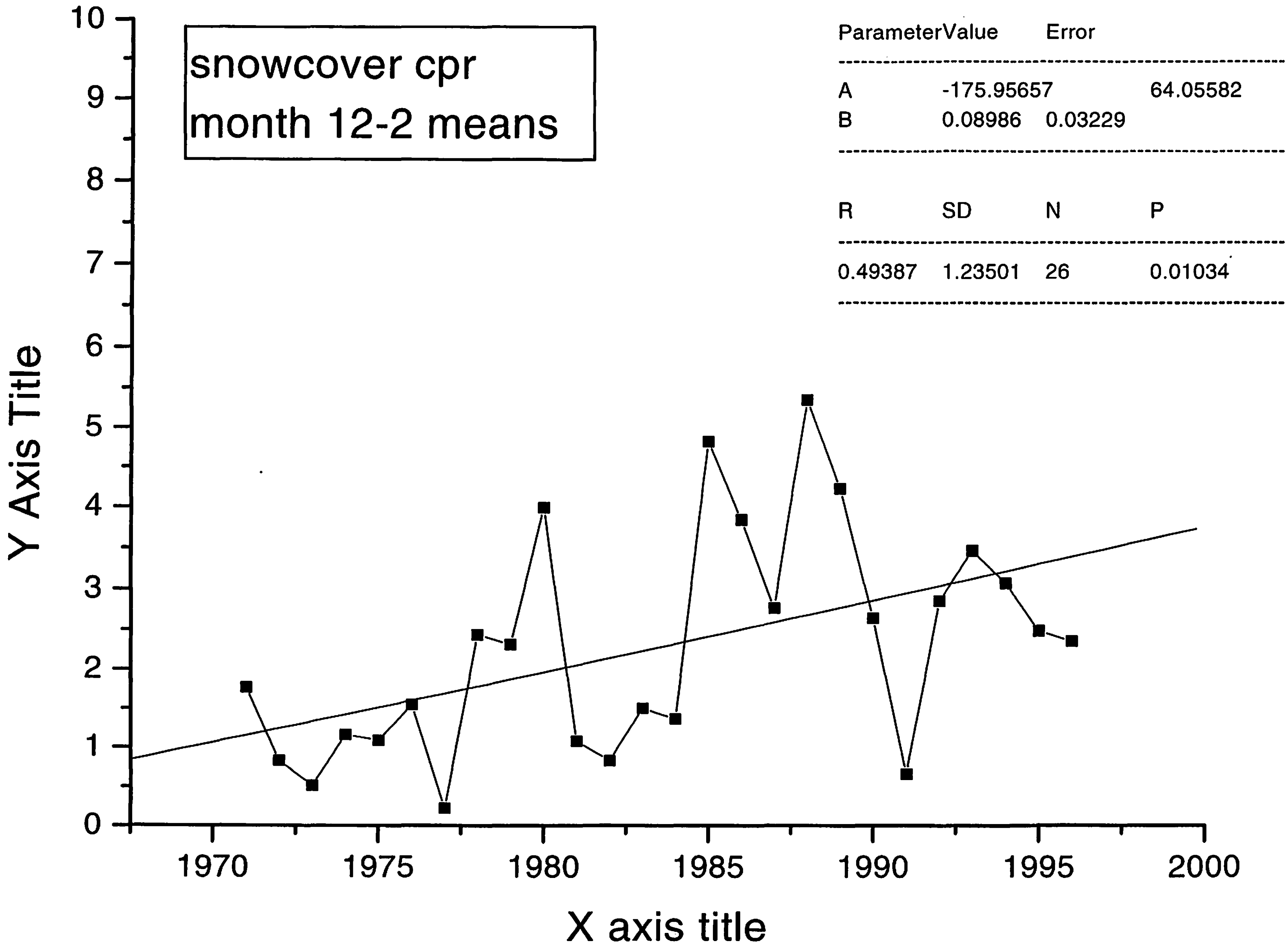

# Growing Season Temperatures

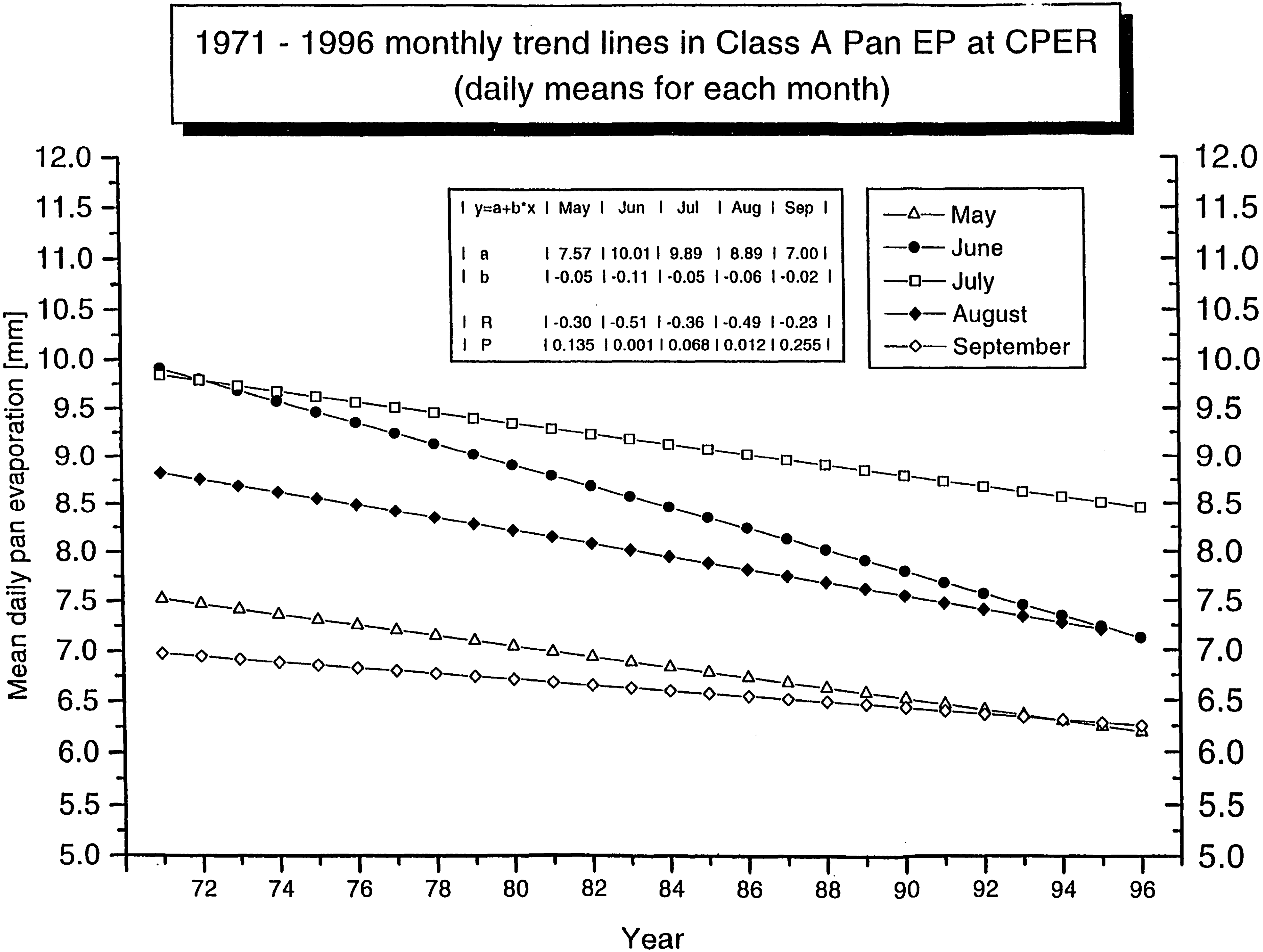


## 1971 - 1996 monthly trend lines in wind at CPER (monthly means)

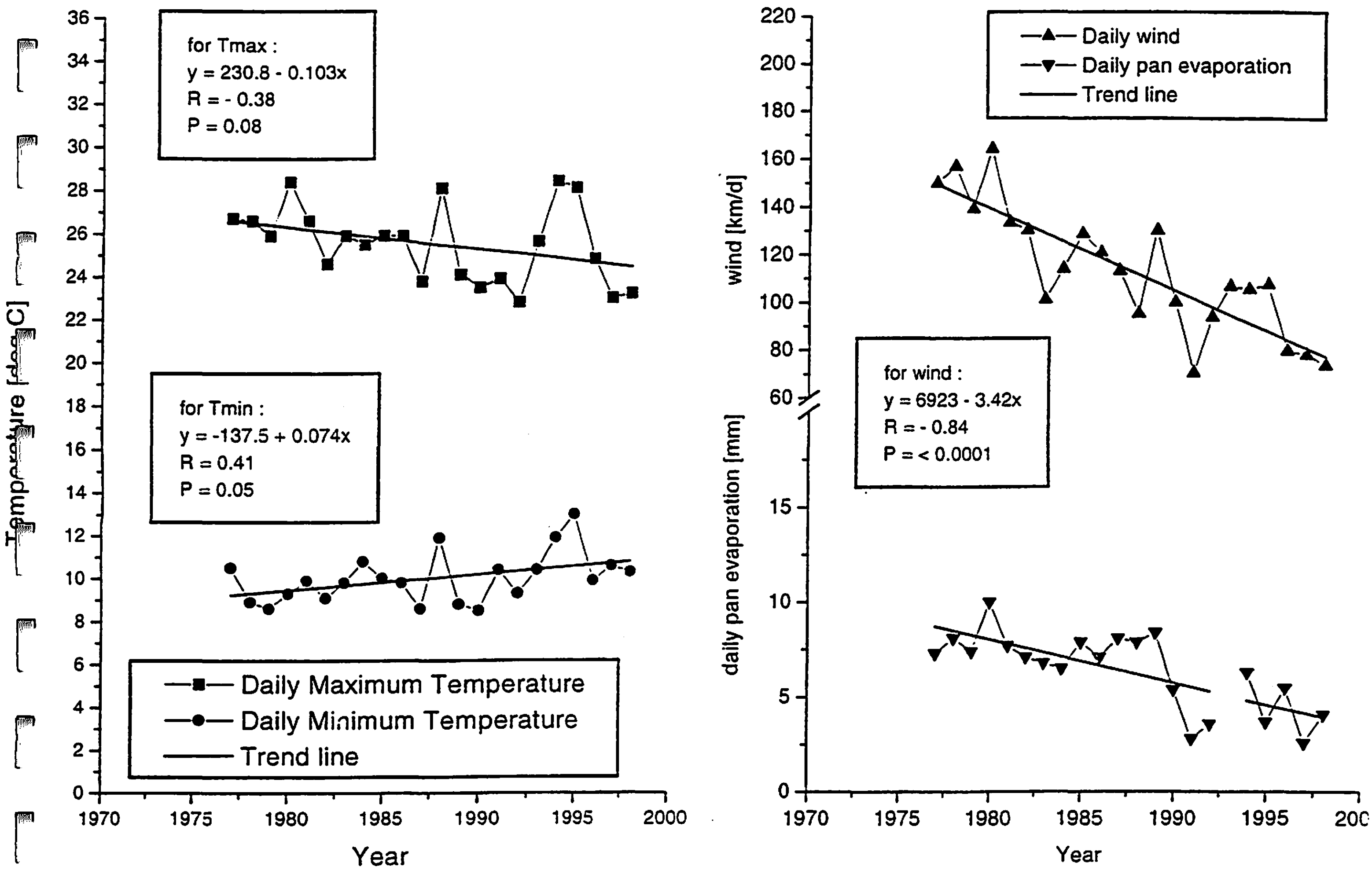



| y=a+b*x | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|
| a | 287 | 313 | 272 | 261 | 253 |
| b | 0.54 | -1.34 | -0.42 | -0.61 | 0.40 |
| R | 0.06 | -0.41 | -0.12 | -0.22 | 0.14 |
| P | 0.788 | 0.045 | 0.551 | 0.286 | 0.509 |


snowcover cpr
month 12-2 means
ParameterValue Error
A -175.95657 64.05582
B 0.08986 0.03229
R SD N P
0.49387 1.23501 26 0.01034
Y Axis Title
X axis title
0 1 2 3 4 5 6 7 8 9 10
1970 1975 1980 1985 1990 1995 2000


1971 - 1996 monthly trend lines in Class A Pan EP at CPER
(daily means for each month)
| y=a+b*x | May | Jun | Jul | Aug | Sep |
| a | 7.57 | 10.01 | 9.89 | 8.89 | 7.00 |
| b | -0.05 | -0.11 | -0.05 | -0.06 | -0.02 |
| R | -0.30 | -0.51 | -0.36 | -0.49 | -0.23 |
| P | 0.135 | 0.001 | 0.068 | 0.012 | 0.255 |
May
June
July
August
September
Mean daily pan evaporation [mm]
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
72
74
76
78
80
82
84
86
88
90
92
94
96
Year

# 1975 - 1998 trends at Cheyenne / WY (June - August means)



# SUMMARY

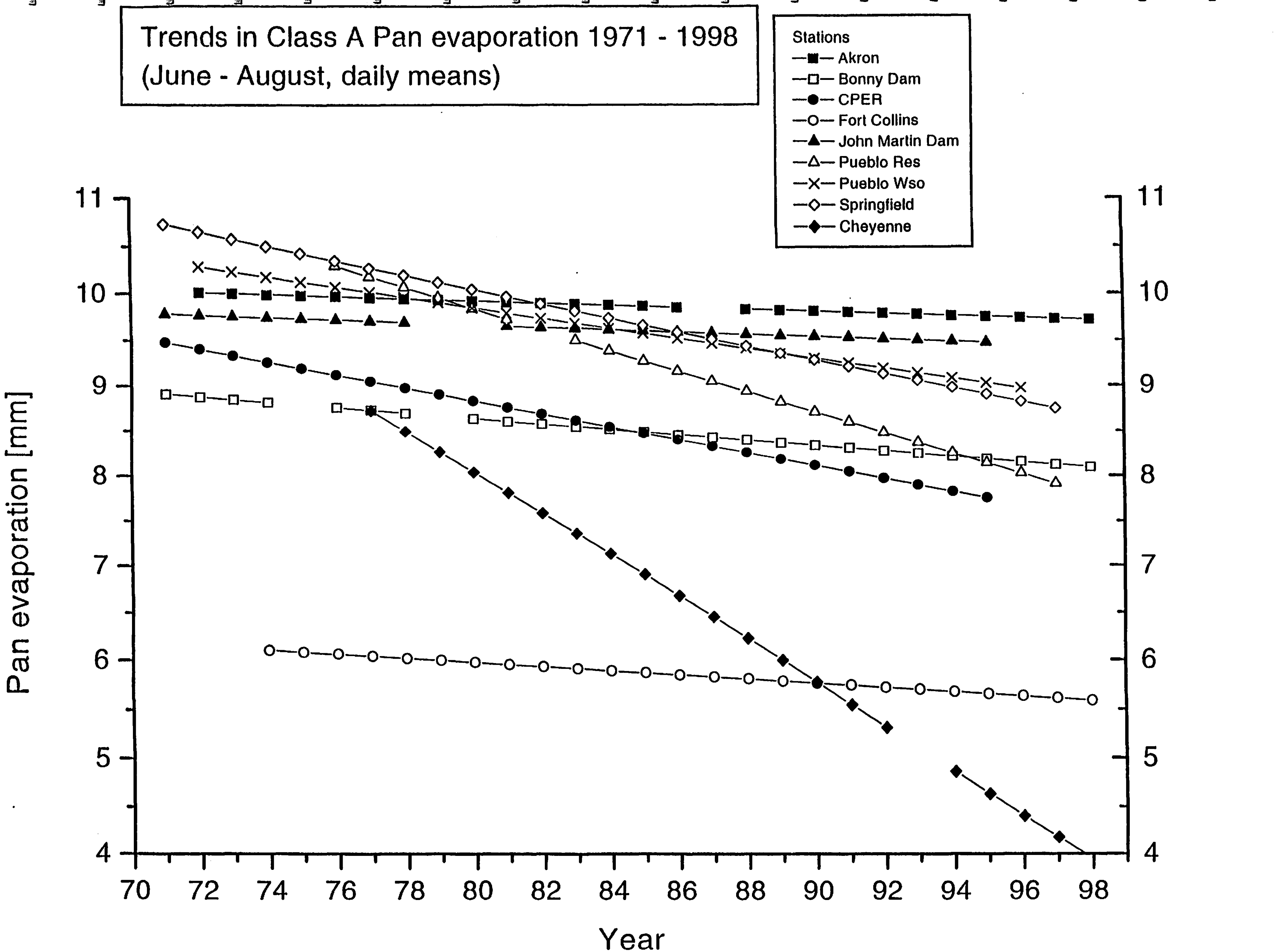
1. Max summer temperatures are decreasing. Min summer air temperatures are increasing.

2. Summer wind speeds are decreasing.

3. Pan evaporation is decreasing.

4. More rainfall.

5. Greater snow cover.



Trends in Class A Pan evaporation 1971 - 1998
(June - August, daily means)
Stations
Akron
Bonny Dam
CPER
Fort Collins
John Martin Dam
Pueblo Res
Pueblo Wso
Springfield
Cheyenne
Pan evaporation [mm]
Year
11
10
9
8
7
6
5
4
70
72
74
76
78
80
82
84
86
88
90
92
94
96
98

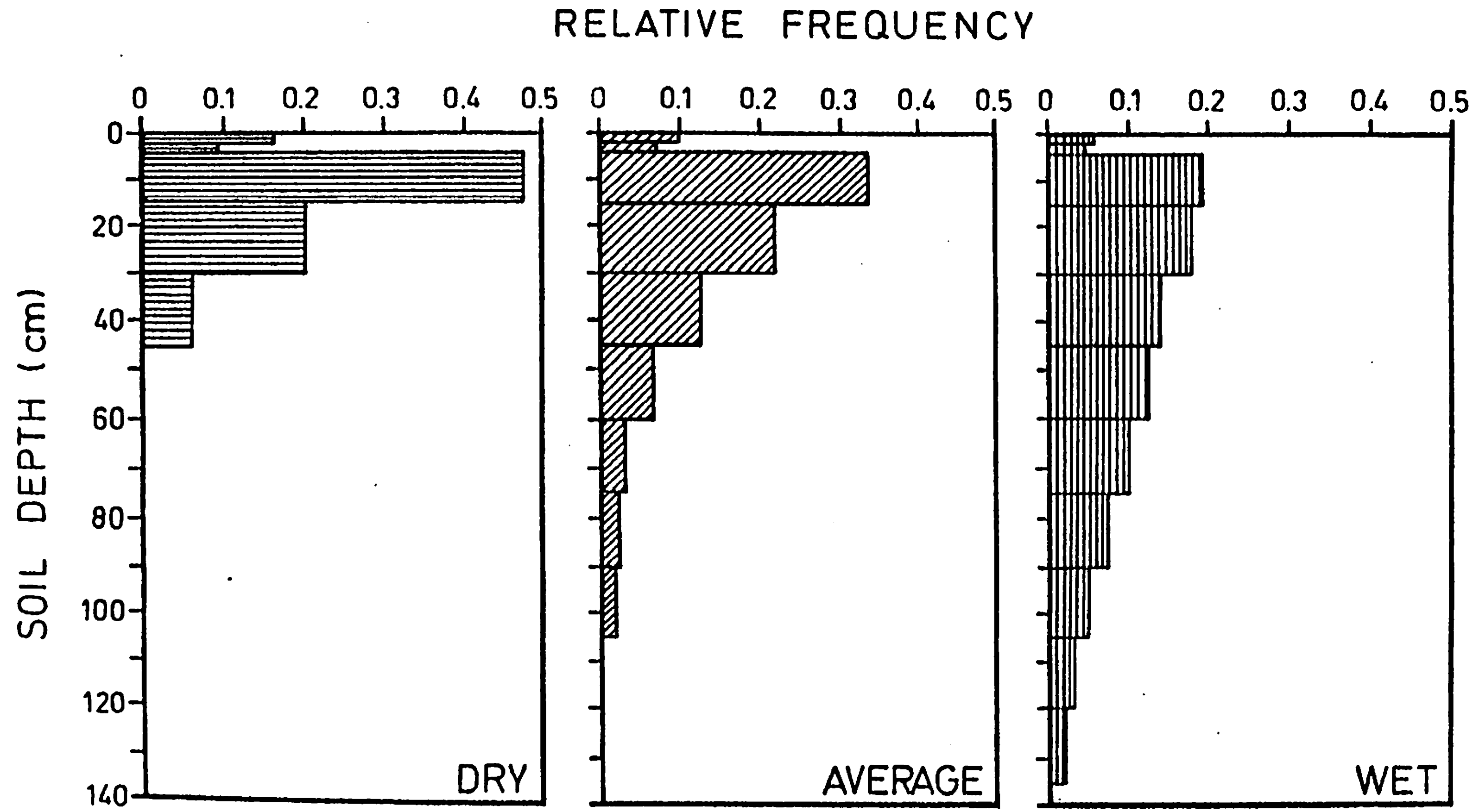
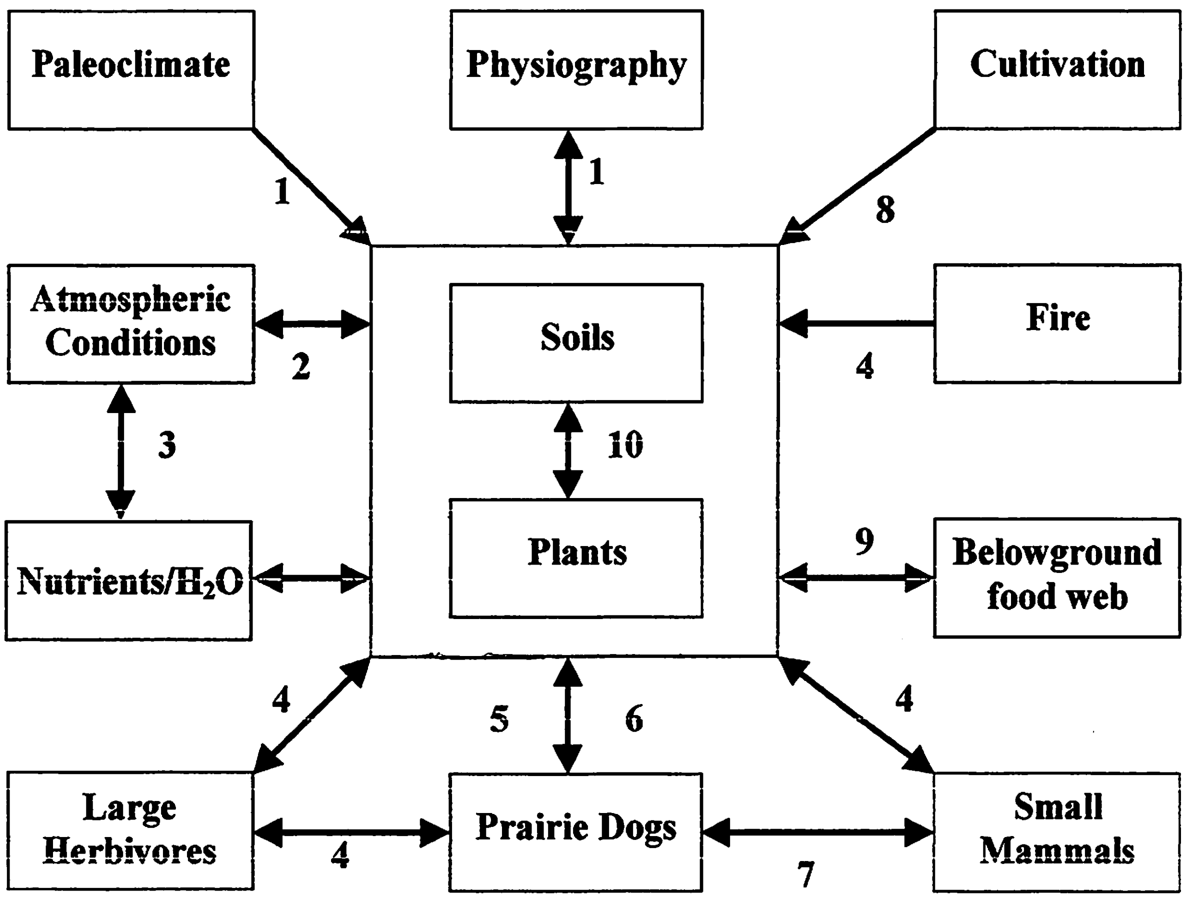



FIG. 8. Relative frequency of available water, as a function of depth in soils of the shortgrass steppe of northcentral Colorado, calculated as the proportion of the total number of wet days (all layers) that occurred in each layer. Wet days were defined as those that had a soil water potential $> -1.0$ MPa. Results from the eight driest and eight wettest years are graphed separately from the remaining 17 yr.

# Plant-Animal Interactions
# Shortgrass Steppe LTER Research Activity Plan




4 Milchunas 6 Detling 10 Lauenroth 8 Burke 9 Moore

## *Plant-Animal Interactions Research*

### *Conceptual Model:*

The shortgrass steppe is among the most grazing tolerant systems in the world (Fig. 1). The basis for our conceptual model explaining this concerns the evolutionary convergent selection pressures of grazing and semiaridity versus divergent selection pressures in productive environments (Fig. 2, Am. Nat. 132:87). Semiarid systems have relatively greater proportions of biomass in roots and crowns that are inaccessible to large herbivores, and consumptive alteration of the plant canopy does not greatly alter competition for light. A long evolutionary history of grazing by native herbivores produces species tolerant of grazing.

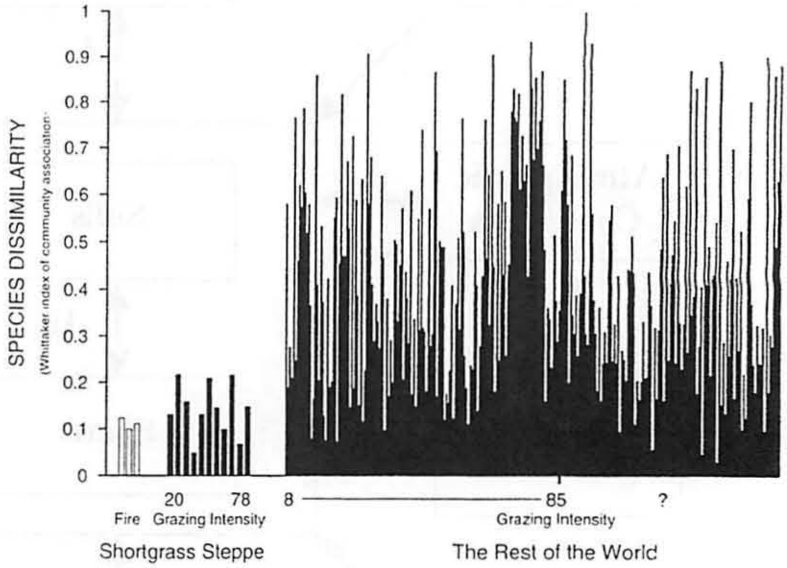



Fig. 1. Change in shortgrass steppe plant community composition due to grazing compared with other systems around the world. Other aboveground disturbances, such as fire, also have relatively little impact on shortgrass steppe.

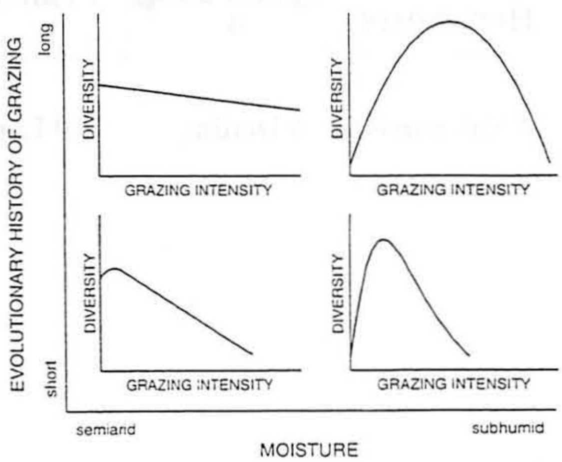



Fig. 2. Conceptual model of response of different grasslands to grazing. The shortgrass steppe is represented by the upper-left condition.

***Experimental Results:***

I) Cattle

1) Effects on Plant Community:

Overall minor impacts on species composition, productivity or roots. Increases in basal cover with grazing rather than decreases.

Ungrazed more similar to disturbed communities than heavily grazed, cattle are somewhat of a surrogate for bison.

Grazed less likely to be invaded by exotics or 'weeds'. Experiments suggest this is due to a more uniform exploitation of soil volume, and indirect, longer-term mechanisms rather than current-year defoliation effects (Fig. 3).

Grazing interactions with Opuntia indicate that the cactus is not a primary reason for observed responses, is not a keystone species, but does have some positive effects as micro-refugia from grazing (Table 1).

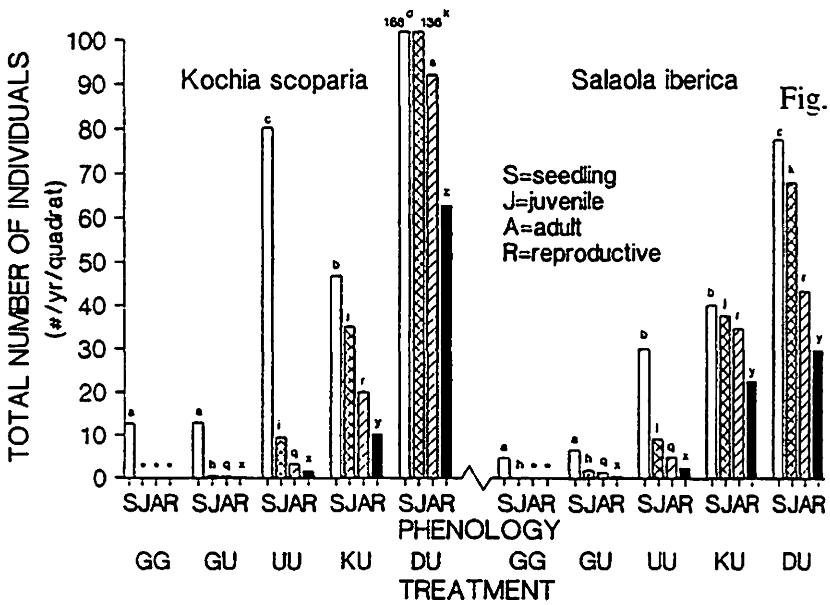



Fig. 3. Total number of individuals of two weed species that attained seedling, juvenile, adult, and reproductive phenologies on GG- long-term grazed, currently grazed, GU- long-term grazed, currently *u*ngrazed, UU- long-term *u*ngrazed, currently *u*ngrazed, KU- vegetation *k*illed, *u*ngrazed, and DU- vegetation removed, soil *d*isturbed, *u*ngrazed.

| | Ungrazed | | Moderately grazed | | Grazing effects | | Cactus effects | |
|---|---|---|---|---|---|---|---|---|
| | in cactus | Out cactus | in cactus | Out cactus | in cactus | Out cactus | ungrazed | Grazed |
| Grasses | 15.24 | 14.92 | 10.81 | 10.11 | | (-) | | |
| Forbs | 4.36 | 5.04 | 4.39 | 3.54 | | (-) | | |
| Shrubs | 3.31 | 5.91 | 1.35 | 2.34 | (-) | - | - | |
| Barrel-cacti | 0.04 | 0.12 | 0.06 | 0.03 | | - | | |
| Annuals | 0.46 | 0.97 | 0.69 | 1.04 | | | (-) | |
| Perennials | 22.54 | 25.03 | 15.92 | 15.02 | - | - | (-) | |
| Cool-season | 18.16 | 19.69 | 9.70 | 7.33 | - | - | | (+) |
| Warm-season | 4.73 | 6.19 | 5.85 | 3.70 | | (+) | | |
| Cool-season annual grasses | 0.00 | 0.00 | 0.006 | 0.05 | | (+) | | |
| Cool-season annual forbs | 0.19 | 0.30 | 0.11 | 0.24 | | | | - |
| Cool-season perennial grasses | 11.26 | 11.15 | 5.51 | 3.44 | - | - | | + |
| Cool-season perennial forbs | 2.59 | 2.87 | 2.91 | 1.78 | | - | | + |
| Warm-season annual forbs | 0.29 | 0.67 | 0.57 | 0.74 | (+) | | | |
| Warm-season perennial grasses | 3.42 | 3.77 | 5.29 | 5.61 | | (+) | | |
| Warm-season perennial forbs | 3.42 | 3.77 | 3.29 | 5.61 | | | | |
| Cool-season shrubs | 3.12 | 5.36 | 1.15 | 1.80 | (-) | - | - | |
| Warm-season shrubs | 0.19 | 0.55 | 0.20 | 0.57 | | | | |
| Exotics | 0.13 | 0.34 | 0.14 | 0.10 | | - | (-) | |
| Weeds | 6.77 | 10.65 | 7.62 | 7.19 | | (-) | - | |
| Species without asexual reproduction | 18.79 | 21.33 | 14.33 | 11.94 | - | - | (-) | (+) |
| Selected for by cattle | 13.02 | 12.53 | 5.25 | 4.71 | - | - | | |
| Not selected for by cattle | 9.40 | 12.57 | 9.47 | 10.54 | | | - | |
| Increasers | 0.15 | 0.54 | 0.20 | 0.37 | | + | | - |
| Decreasers | 13.02 | 14.80 | 4.31 | 3.15 | - | - | (-) | |
| Indifferents | 9.80 | 10.37 | 12.12 | 12.47 | | | | |

Table 1. Aerial cover (%) of functional groups for each of the combinations of grazing treatment and inside and outside of cactus refuges. +- within bracket = $p<0.1$, no bracket = $p<0.05$

2) Plant Physiological Responses:

Effects of defoliation during the current year on tiller biomass (decrease), %N (increase), and N-yield (increase) of western wheatgrass were greater and more consistent than effects of long-term exclusion from grazing.

Current year defoliation and long-term grazing of blue grama had no consistent effects on tiller biomass, %N, or N-yield.

Rate of photosynthesis per unit leaf area and stomatal conductance were greater in western wheatgrass in long term protected areas than in grazed pastures.

Rate of photosynthesis of blue grama was not affected by long-term grazing history.

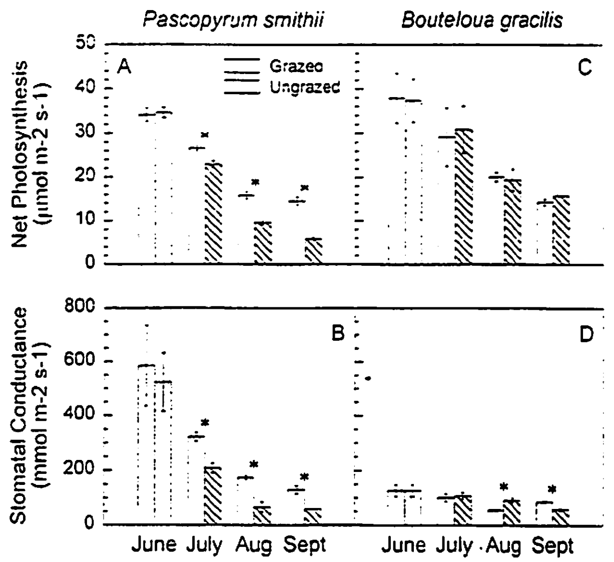



Fig. 4. Rates of net photosynthesis and stomatal conductance for western wheatgrass (*P. smithii*) and blue grama (*B. gracilis*) in a longterm grazing exclosure and an adjacent heavily grazed pasture. Gas exchange was measured on single leaves of each species. Asterisks indicate significance at P<0.05.

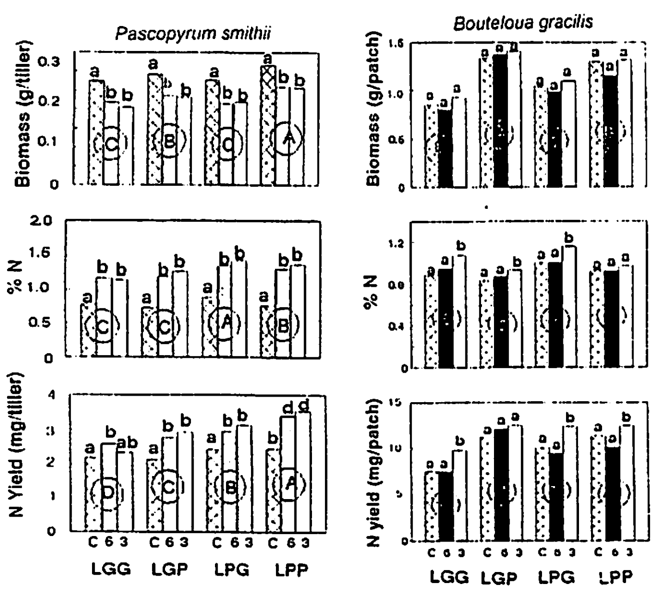



Fig. 5. Responses of western wheatgrass (*P. smithii*) and blue grama (*B. gracilis*) to long-term grazing history and defoliation. Symbols are as follows: LGG = long-term grazed and still grazed, LGP = long-term grazed and now protected, LPG = long-term protected and now grazed, LPP = long-term protected and still protected; C = control (unclipped), 6 = clipped to 6 cm height, 3 = clipped to 3 cm height.

3) Effects on Biogeochemistry:

Total C & N affected only at heavy grazing intensities in more heavily utilized lowland topographical locations.

Slightly less coarse POM C & N with grazing.

Grazing has only small influence on spatial variability of soil organic matter; a conclusion very different from the Schlessinger model for the southwestern US.

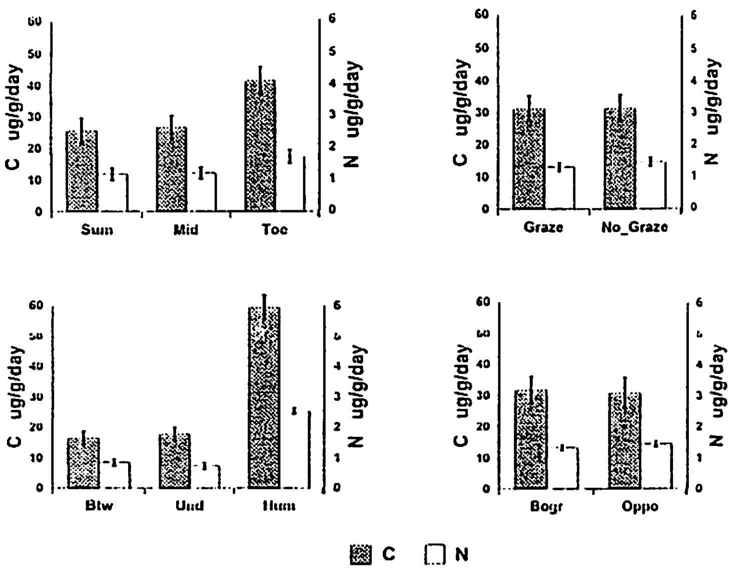



Fig. 6. Carbon and nitrogen mineralization rates along topographic sequences (Sum=summit, Mid=midslope, Toe=toeslope), from grazing treatments, and associated with individual plants (Btw=between, Und=under, Hum=hummock) of *B. Gracilis* (Bogr)or *O. Polyacantha* (Oppo).

4) Effects on Other Consumers:

Highly variable responses among groups, with birds and aboveground macro-arthropods particularly sensitive.

Consumer responses do not mirror that of vegetation, although bird responses also suggest that heavy grazing was the nominal condition through evolutionary time.

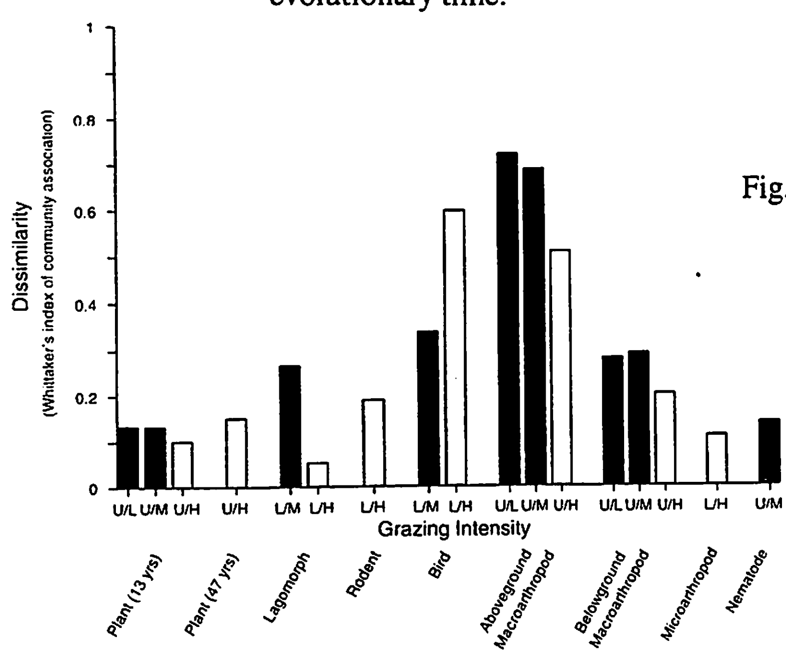



Fig. 7. Community dissimilarity between long-term grazing treatments for various plant, animal, arthropod, and nematode groups. U/L=ungrazed compared to lightly grazed, etc, with M=moderately and H=heavily grazed.

5) Interactions with Elevated $CO_2$:

No interaction between defoliation and $CO_2$ has been observed for aboveground primary production, although both $CO_2$ enrichment and defoliation increased production.

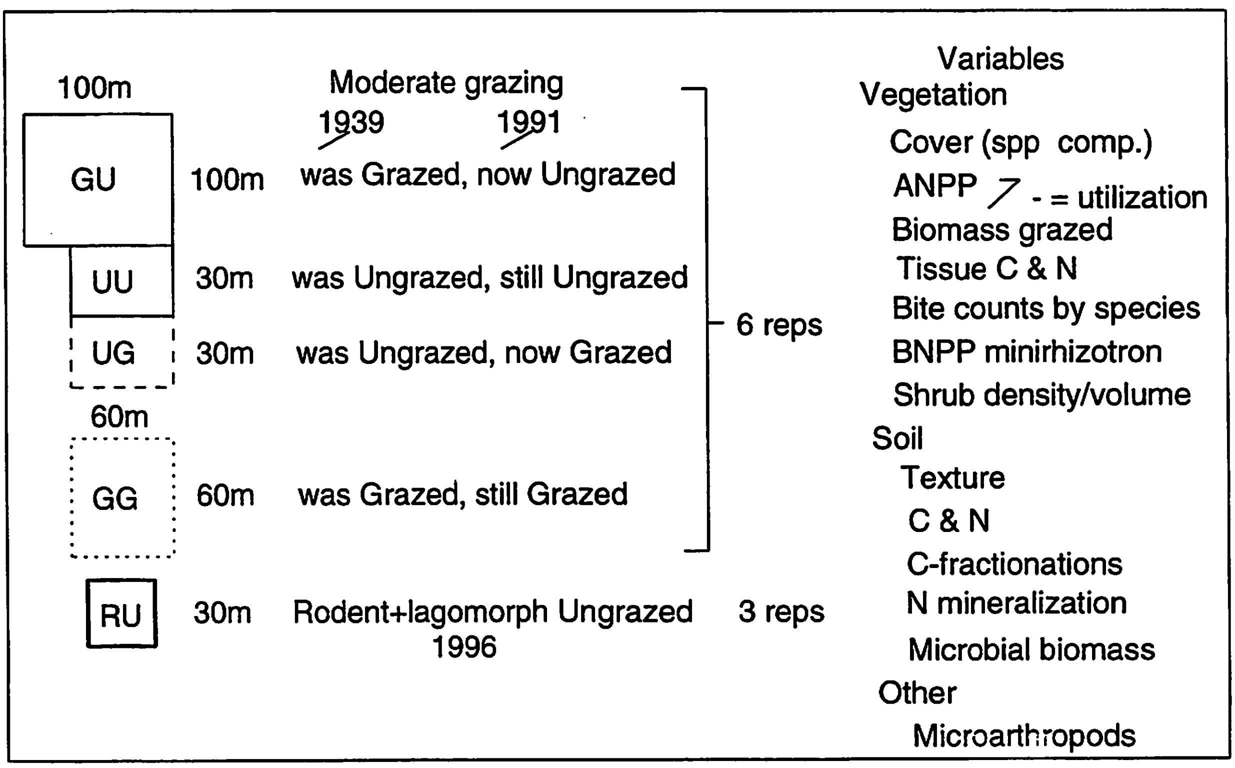
Studies are currently underway to assess tissue quality and digestibility as affected by elevated $CO_2$.

II) Small Mammals

1) Rodents and Lagomorphs:

Cross-site LTER study is testing hypothesis that small mammals, due to selectivity, may have greater impact in systems of low productivity, while large mammals have greater impact in more productive systems.

Exclosures that keep rodents and lagomorphs out compliment those excluding only large herbivores.




2) Prairie Dogs and P-Dog by Cattle Interactions:

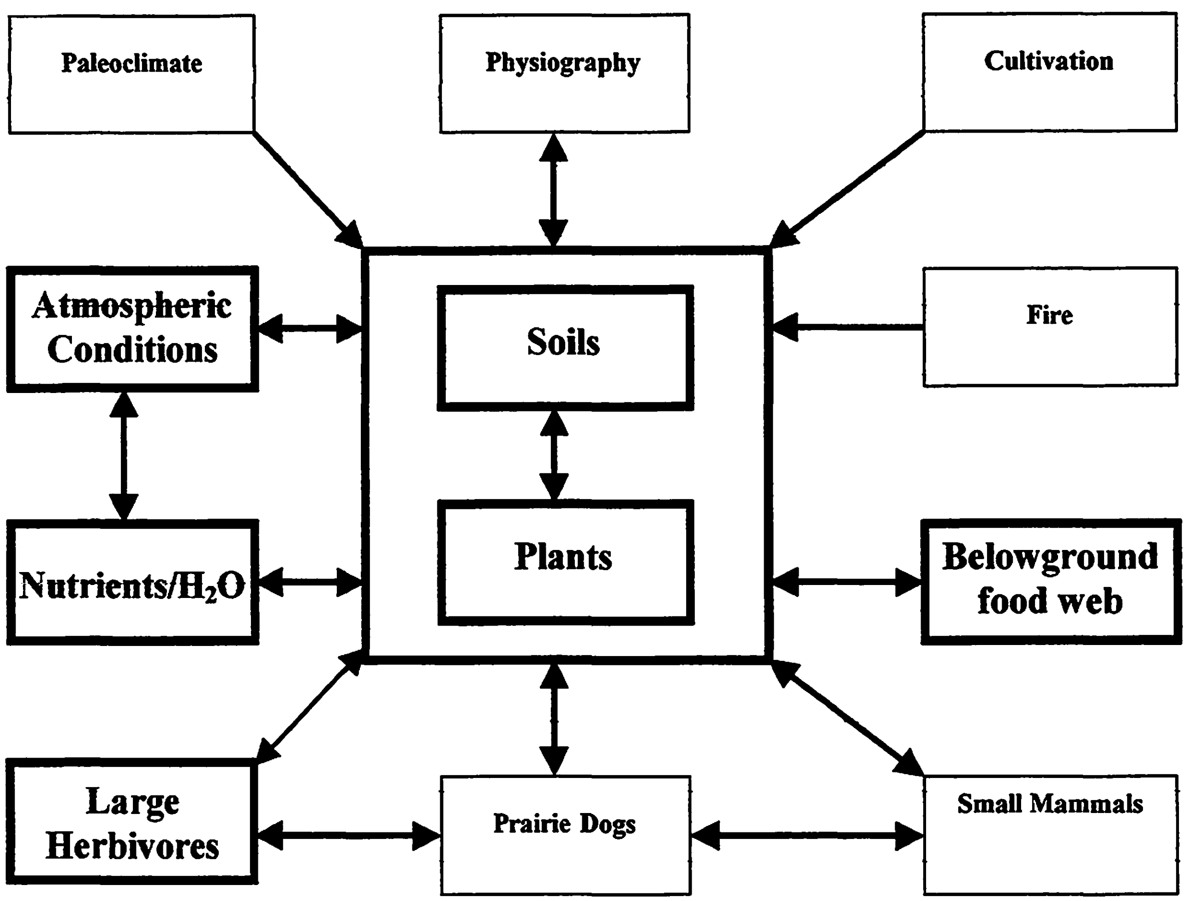
Assessing whether P-dogs are a keystone species providing habitat for other consumers through their effects on vegetation.

Starting study that assesses P-dog interactions with cattle; do cattle preferentially utilize higher quality but lower production on towns.

**Long-Term Impact of Elevated $CO_2$ on Shortgrass Steppe Ecosystem Dynamics and Trace Gas Exchange.**

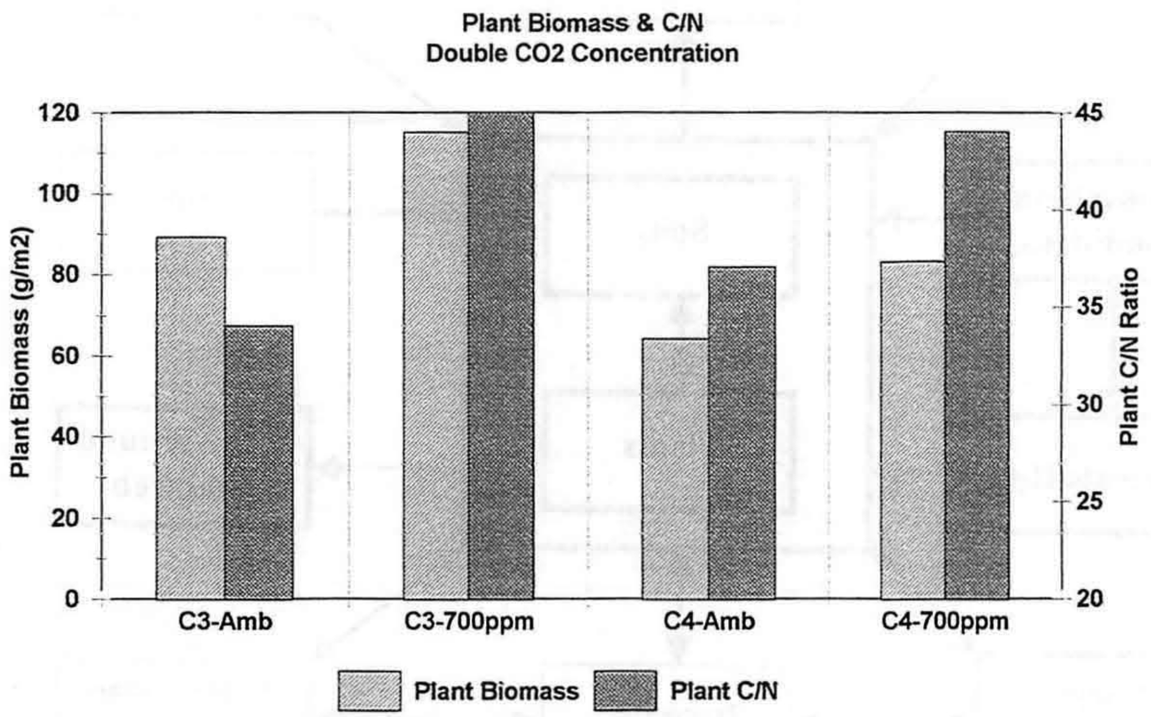
**[3]Arvin Mosier, Jack Morgan, Dan Milchunas, Bill Parton, Dennis Ojima, Mike Coughenour, John Moore**

**Shortgrass Steppe LTER Research Activity Plan**




In September, 1995 we received an initial Terrestrial Ecology and Climate Change (TECO) grant (NSF-IBN-9524068) to determine the effect of doubling $CO_2$ on the Colorado shortgrass steppe. Large open top chambers (OTCs) were constructed and seasonal $CO_2$ enrichment was begun in 1997 to investigate the effects of elevated $CO_2$ (~700 ppmv) on net primary production, photosynthesis and water relations of dominant $C_3$ and $C_4$ species, above and below ground C and N allocation, soil microbial interactions, soil water and N dynamics, and the influence of all of these factors on trace gas fluxes. In May, 1998 a second TECO award (USDA/NRICGP-98-134) provided for continuation of the OTC project through 5-y of $CO_2$ enrichment. This project has brought together a team of USDA/ARS, SGS-LTER, other Colorado State University scientists and U. of Colorado scientists with expertise in plant physiology and effects of $CO_2$ on plant metabolism, soil C and N cycles, trace gases, soil biology and ecosystem analysis to address these important changes in our environment that impact ecosystem viability. The project encompases a number of research priorities within the SGS-LTER program as illustrated in the highlighted portion of the figure on the previous page. These relatively long-term studies are required since turnover of roots in the SGS is 5-7 years so the clear effect of $CO_2$ will take several years to be seen. The project The Following are main observations derived mostly from the first year of $CO_2$ enrichment:

- A doubling of $CO_2$ from 350 to 700 mmol $mol^{-1}$ enhanced seasonal aboveground production of shortgrass steppe vegetation 30%.
- No differences were detected in the responsiveness of aboveground biomass of $C_3$ vs. $C_4$ grasses to $CO_2$ enrichment in one field season.




- $CO_2$ enrichment increased soil water content, leaf water potential and photosynthesis in both $C_3$ and $C_4$ shortgrass steppe species.
- Doubling $CO_2$ concentration in the chamber atmosphere increased plant water use efficiency, thus increased average soil water content in soils under double $CO_2$ throughout the year.
- Trace gas ($CH_4$, $CO_2$, $NO_x$, $N_2O$) fluxes were not significantly different between soils under ambient atmosphere compared to those under double $CO_2$ atmosphere.

- Minirhizotron root observations suggest that it will take several more years to reach an equilibrium between production and decomposition, and for the quality of all root material to have been influenced by the $CO_2$ enrichment treatment.

- New root production increased ~30 % under double $CO_2$.

- Nematode populations were not significantly altered after the first year of $CO_2$ enrichment.

- Daily Century Model results suggest that the most important effect of doubling $CO_2$ is to increase root production and soil water content during the growing season.

- Model results suggest increased soil water and root C inputs leads to increases in soil C levels and that soil N also increases as a result of decreased gaseous N losses.

- Several years are likely required before inputs into various organic matter pools are dominated by the influence of elevated $CO_2$ or before significant shifts in plant community structure appear.

**Supplementary Projects**

Since the inception of the project two supplementary projects have been funded: 1) Biotic controls on soil C dynamics and N cycling under elevated $CO_2$, Dan Milchunas (PI), Colo. St. Univ. (NSF-$499,587-3 yr (1998-2000)), and 2) Stable isotope tracers of $CO_2$ fluxes on shortgrass steppe under $CO_2$ enrichment (DOE-NIGEC-$289,695-3 yr (1999-2001)), Elise Pendall (PI), Institute for Arctic and Alpine Research, Univ. Colorado.

Persons directly involved with the SGS-$CO_2$ enrichment studies:

Mike Coughenour--NREL, CSU
Romel Lapitan--NREL, CSU
Dan Milchunas--NREL, CSU--SGS LTER
John Moore--Dept. Biology, UNC--SGS LTER
Jack Morgan--USDA/ARS--SGS LTER
Arvin Mosier--USDA/ARS--SGS LTER
Bob Niles--NREL, CSU
Dennis Ojima--NREL, CSU
Andy Parsons--NREL, CSU
Bill Parton--NREL, CSU--SGS LTER
Elise Pendall--IAAR, UC
Diana Wall--NREL, CSU
Larry Tisue--Technician funded half time by LTER

List of abbreviations: ARS = Agricultural Research Service; CU = University of Colorado (Boulder); CSU = Colorado State University; IAAR = Institute of Arctic and Alpine Research; SGS = Shortgrass Steppe; NREL = Natural Resource Ecology Laboratory ; UNC = University of Northern Colorado; USDA = United States Department of Agriculture

# Shortgrass Steppe Research on Black-Tailed Prairie Dogs (*Cynomys ludovicianus*)

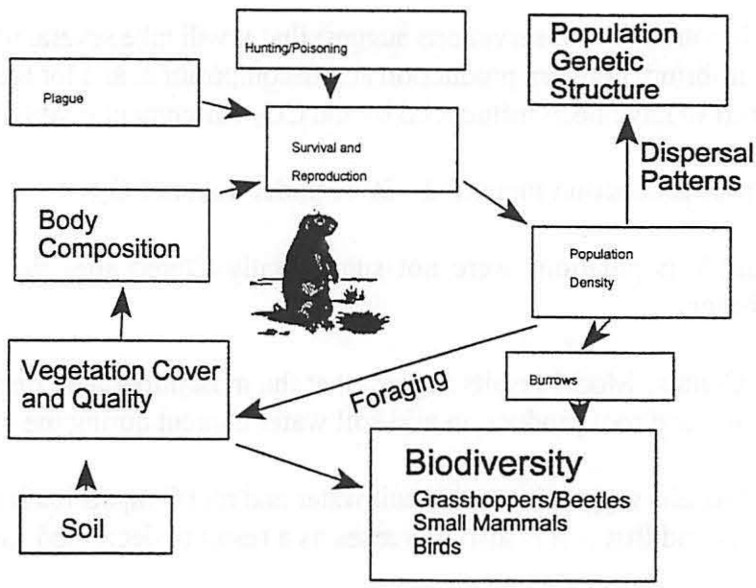



Figure 1. Important functional relationships for black-tailed prairie dogs on the Shortgrass Steppe

Personnel

Bea Van Horne, SGS LTER Co-PI, Professor of Biology
Jim Detling, SGS LTER Co-PI, Professor of Biology
Paul Stapp, Postdoctoral Associate UC Davis; small mammals, herps, birds
Deb Guenther, Research Assistant, cattle vs prairie dog foraging
Jeanine Junell, Research Assistant; arthropods
Jason Woodard, Research Assistant; Burrowing Owls
Erin Lehmer, Research Assistant; diet/physiology
Jennifer Roach, Research Assistant; genetics/metapopulation
John Norman, REU; GIS and history of prairie dogs on site
Melissa Andre, REU; Bird diversity and nesting success on colonies

## Research Objectives

1. Describe factors that influence prairie dog colony location in the Shortgrass Steppe
2. Understand "bottom-up" physiological parameters of prairie dogs on the Shortgrass Steppe
3. Describe metapopulation dynamics and genetic patterning in prairie dogs
4. Understand the role of prairie dogs in influencing plant and animal diversity on the Shortgrass Steppe
    a. Arthropods
    b. Small Mammals
    c. Snakes, lizards, amphibians
    d. Burrowing owls
    e. LTER hypothesis 2.4:

"Prairie dogs are keystone species in the shortgrass steppe and exert both 'top down' and 'bottom up' control on trophic structure because of their ability to influence the quantity and quality of net primary production, as well as their role as critical prey species for both mammalian and avian predators"


Fig. 2. Ranges of Prairie dog species in the U.S. Only the black-tailed prairie dogs are considered non-hibernators.

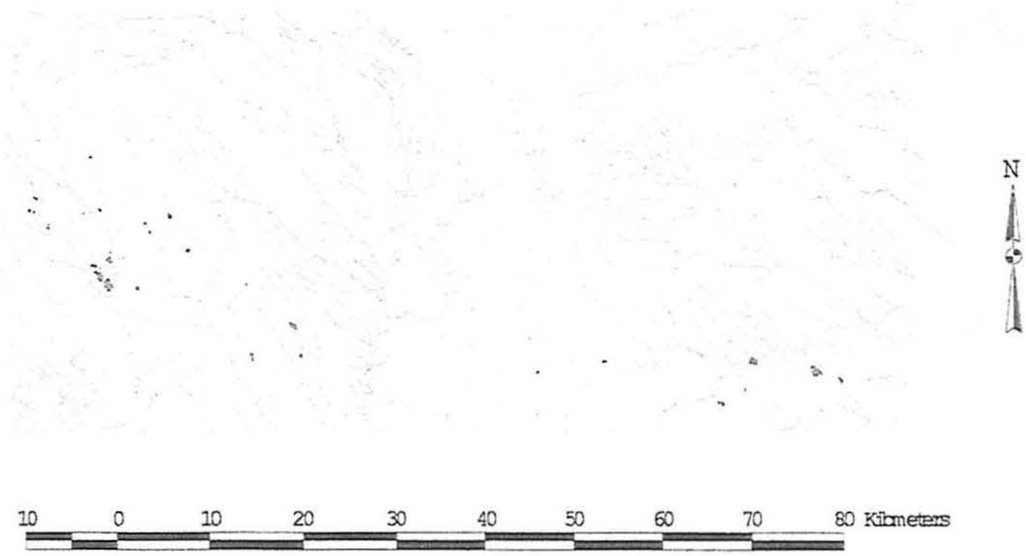



Fig. 3. Prairie dog colonies on the SGS LTER. Colonies on the CPER are not shown.

Fig. 4. Prairie dog colonies overlaid on soils map.

| Soil Type | Percent Area of LTER | Percent Area of Prairie Dog Towns |
|---|---|---|
| Ascalon Fine Sandy Loam | 14 | 30-33 |
| Olney Fine Sandy Loam | 11 | 3 |
| Platner Loam | 7 | 28-29 |

Table 1. Soil types on which colonies are located.

## Research Questions about the Effects of Prairie Dogs on Vegetation

- How do prairie dogs affect plant species composition and biomass?
- How do prairie dogs affect plant nitrogen concentration and content?
- How is cattle foraging behavior influenced by the presence of prairie dogs?

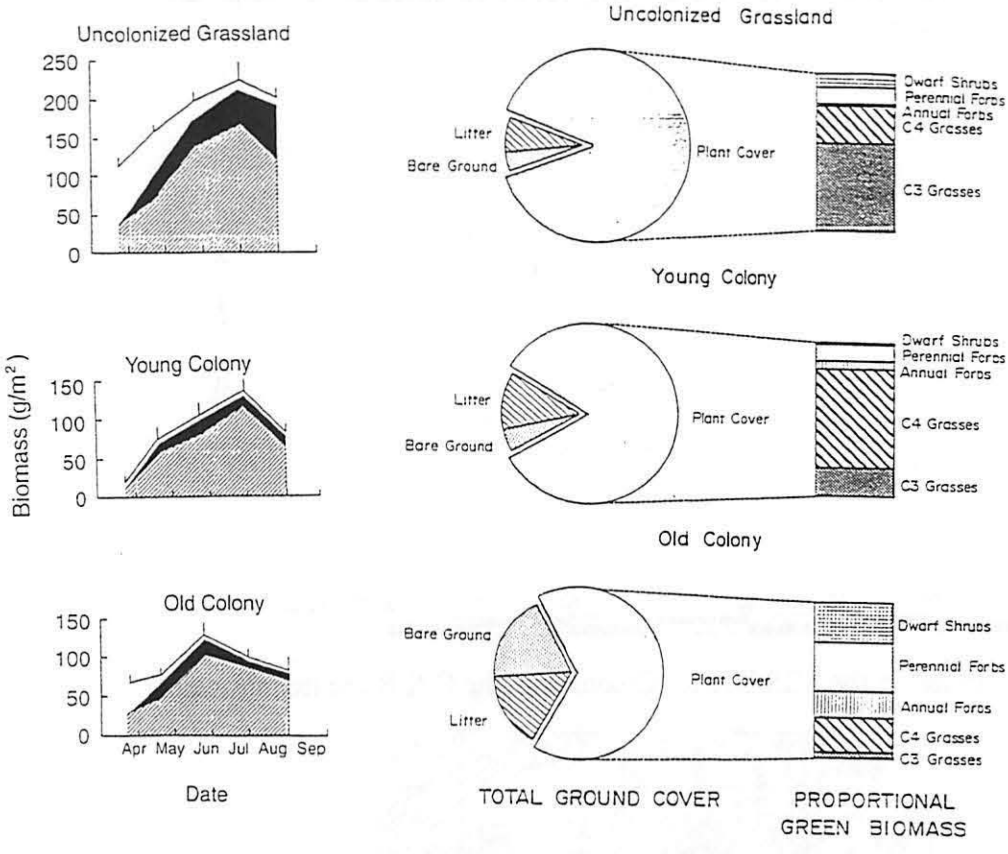



Fig. 5. Effects of prairie dogs on vegetation in mixed grass prairie. We will compare this with effects in the shortgrass steppe.

## Research questions about prairie dog diet/physiology

- Do black-tailed prairie dogs drop body temperatures and become torpid?
- Are their diets lacking in any of the unsaturated fats that have been shown to play a role in torpor?
- Is there a relationship between fatty acids in their food and reproduction?
- How does body composition change when food is less available in winter?

## Results of ongoing metapopulation work

- Drainages are important dispersal corridors
- Ongoing dispersal has a strong impact on genetic structure
  - Frequent extinction/recolonization
  - No inbreeding at present
  - Alleles widespread

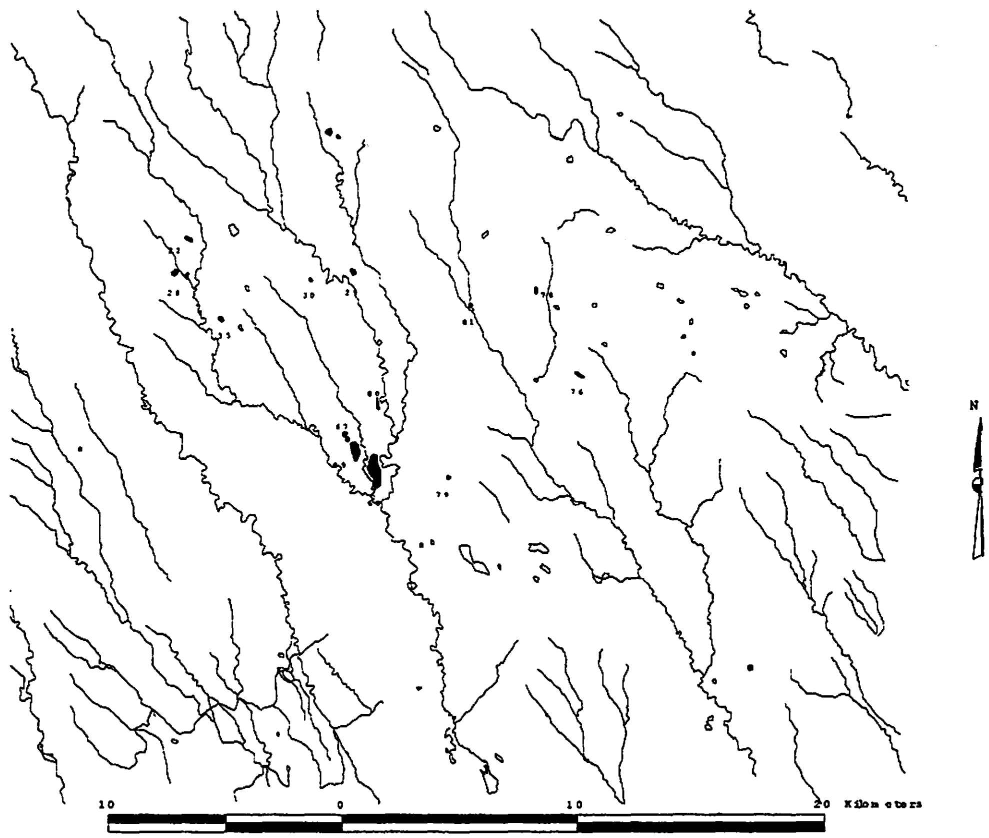



Fig. 6. Prairie dog colonies and drainages on western side of SGS LTER.

## Are prairie dogs keystone species?

On the shortgrass steppe, burrow construction may have more influence than does grazing by prairie dogs

- Burrows may favor darkling beetles, some lizards, snakes, and burrowing owls
- There may be increases in predators on these species, including grasshopper mice, raptors, badgers, etc. (and associated decreases in 13-lined ground squirrels?). Also increased predation on bird nests.
- Surface disturbance and lower vegetation cover/structure favors some annuals, some grasshoppers, horned larks

**Information Management at the Shortgrass Steppe LTER**
**Chris Wasser, Information Manager**

## Mission

The primary goal of data management is to provide long term storage and maintenance of the Shortgrass Steppe LTER data and access to the data by LTER scientists and the general public. The design of our archival procedures, relational database management system, and web-based data access system are all oriented toward achieving this goal. In providing access to SGS LTER data by scientists at Colorado State University, we are also considering the needs of scientists' worldwide to access the data. The second goal for data management is to assist LTER scientists in the analysis of the data and the use of the data in modeling activities.

## Overview

Information management ideally starts before data collection is ever started at the site. The data management staff works with investigators to develop data entry forms and procedures for data collection. These forms are designed to ensure that all necessary auxiliary data are recorded, that data can be accurately transcribed from the forms, and if possible that data can be stored in the original format. The staff also helps investigators prepare additional documentation for the data sets. Close communication between the information management staff and the scientists is a critical component of our information management system. This communication occurs at several points throughout the data management process (Figure 1).

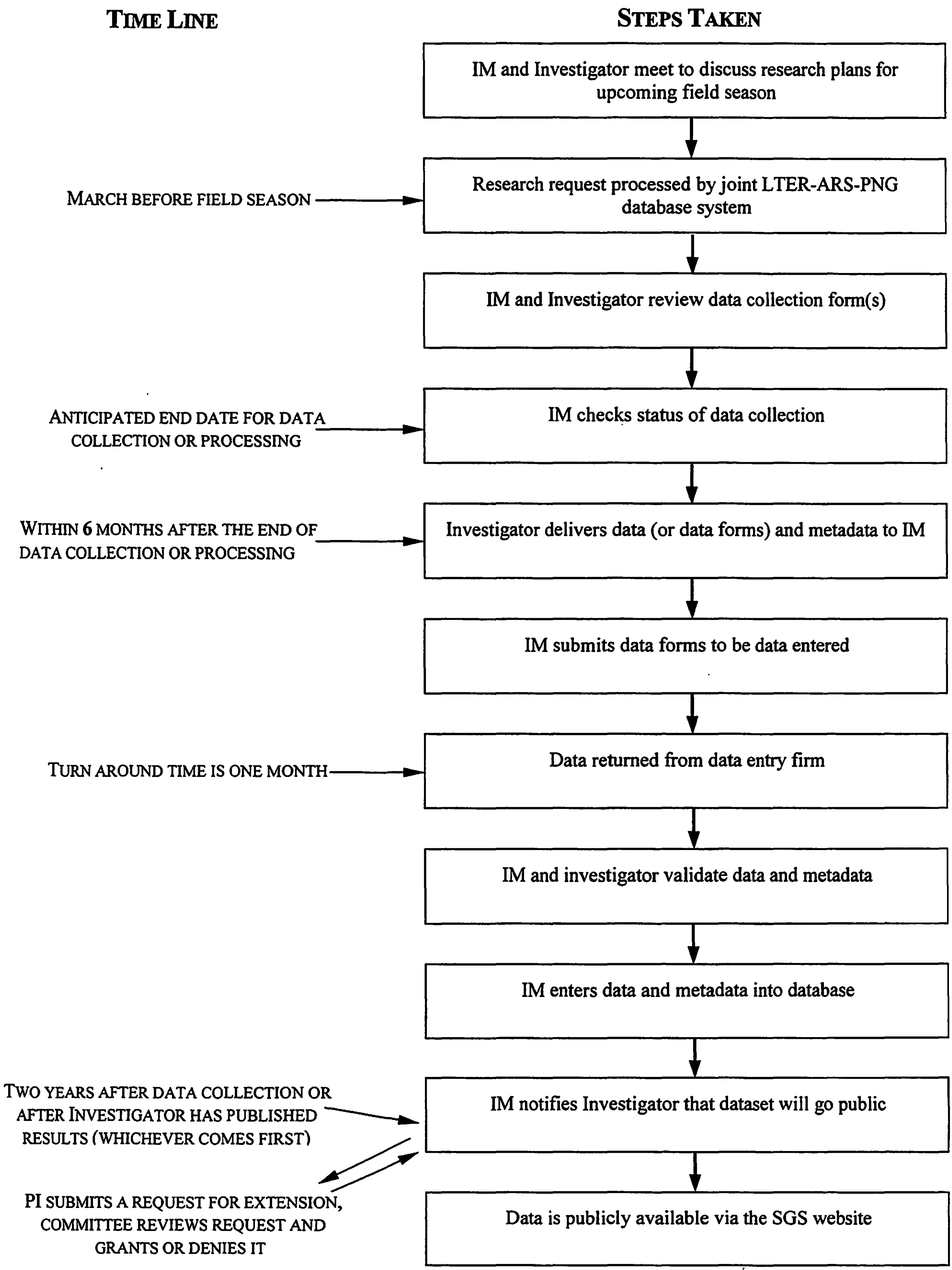
Our information system is based on a relational database (MS Access) and the use of internet technology to disseminate these data. Database-Internet connectivity applications are currently being developed using MS InterDev and Visual Basic code, served with MS Internet Information Server, and our new website has been developed with MS FrontPage. The integration between each all of the software elements of our information management system has allowed us to rapidly develop new applications for use by LTER scientists and the general public.

All of the datasets from field experiments are stored on our Windows NT 4.0 Server, with 18GB of RAID 5 storage. The redundancy of a RAID storage system, when combined with regular full, and incremental, backups provides an extremely high level of archival security. Additional data, such as modeling results and GIS data, are stored on drives connected to UNIX workstations and are backed up on a daily basis by College of Natural Resources staff. We have recently purchased a 100GB RAID 5 storage device to provide archival storage space and large workspace area for memory intensive analyses such as modeling or GIS. Permanent archival of data is accomplished through the use of recordable CD's.

## Progress during the current grant cycle

Significant progress has been made in the first three years of this grant cycle. In 1995, the SGS LTER information management system consisted of flat ASCII text files, with a cumbersome proprietary internet access program. Much of the data consisted of datasets from the International Biome Project, with few current datasets available. The first step was to contact every researcher associated with the SGS LTER project for the past five years and collect as

# Figure 1: Information Management Process



much data as possible. This data collection process has continued to the present and has resulted in the identification and storage of over 200 datasets and much of the associated metadata.

Next we implemented a relational database management system to store our data – field, personnel, and publications. We selected the ORACLE RDBMS engine to store and serve our data and proceeded to import every dataset that was open to public access. This process alone took several months to accomplish. Database design and development required nearly nine months of data management time.

In 1996-1997 we completely redesigned our website and coded database-web applications to serve field, personnel, publications, and species data via our website. Utilizing ORACLE's web connectivity software and PL/SQL programming language all major components of our information management system were searchable via the internet. However, due to increasing costs associated with the ORACLE system and the high level of administrative overhead associated with ORACLE, we decided to migrate our data into MS Access.

During the better part of 1998 and 1999 we have dedicated information management personnel to the migration from ORACLE to Access and the complete redesign of our website to give a more consistent and professional look and feel. All of our web pages are now managed and updated using a single software program (MS FrontPage), utilizing templates for a consistent presentation across all segments of our web site. In addition, we have re-engineered our data access applications using MS InterDev and MS Access. Currently, the personnel, publications, and the metadata applications are complete.

**Future goals of information management**

The highest priority goal for information management staff is to finish the development of the field data application. This will involve developing an on-line query tool to allow the creation of data files, which are subsets of the entire data table. These applications are extremely helpful for files such as the daily meterological data, which may have several thousand rows. These on-line queries would then create ftp files that would be automatically downloaded to the user's PC. In addition, we plan to rebuild the species searching application and add as many pictures to this database as possible.

Another priority goal of information management at the SGS LTER is to develop an integrated information management system to share information between the LTER, Agricultural Research Service, and Pawnee National Grasslands groups. Such a system would allow each group to centrally manage experiment information such as permissions, annual reports, and summary reports. We plan to incorporate a GIS map server, with on-line analytical capabilities. We envision that such a system will encourage better communication between the groups and allow us to more efficiently manage shared information.

Medium range goals include:

- Developing better links between our publications database and our datasets to allow seemless browsing between these datatypes
- Providing a link to abstracts of publications (where possible)
- Importing more datasets into our Access database
- Developing summary weather applications for use by modelers

## Geographic Information System (GIS) Research Support and Data Management

Martha B. Coleman
SGS-LTER GIS Data Manager

The primary goal of the SGS GIS program is to provide easy data access along with technical and analytical support for members of the SGS-LTER research community. This goal is accomplished through five main functions: (1) data acquisition, (2) analysis support, (3) data management, (4) internet access, and (4) data archive.

**Data Acquisition:** The collection of new data, extension of existing spatial data, and maintenance of metadata are the focus of our data acquisition activities. The newest data layers are (1) the digital version of the Northern Weld County Soil Survey and (2) the field study location updates using global positioning system (GPS) technology. The soil survey covers the entire Pawnee National Grassland (PNG) and was a preliminary release without an accompanying digital database. We extended this map by automating approximately 10 data fields (e.g. soil name, soil texture) to provide immediate use by our researchers, and are awaiting the release of the full digital database. The GPS data collection of field sites was partially implemented over the past two years, and with the purchase of our own Trimble Geoexplorer unit should be fully operational in the fall of 1999. A set of data collection procedures have been created to help insure the quality of the GPS data. After the data are collected by the researcher or field crew, the GIS manager validates, differentially corrects, converts to Arc/Info format, generates metadata, and archives all associated files.

**Analysis Support:** GIS research analysis is conducted primarily using Arc/Info and IMAGINE software. These analyses range from plant-level scanning and analysis of root characteristics, to plot-level identification of plant growth and mortality, to landscape-level assessments of nutrient run-off and network modeling of prairie dog movement between towns. These analyses are supported in full or in part based on the needs of the researcher.

**Data Management**: We currently utilize an extended ARC/INFO data library structure for analysis and daily management of spatial data and metadata. These data are then made available across the internet in several formats as needed to accommodate local and remote researchers. Since many users simply wish to view the data, map views similar to those in our map atlas are accessible for viewing in raster format, and downloading in black-and-white or color postscript format for local printing of high-quality graphics.

A new method for access and retrieval of past and present field study sites is now being adopted at SGS. This format stores each study location as a polygon in the Study Site library layer. This new format will allow scientists and data managers to more easily identify past and current research based on plant or animal species, key words, researcher names, dates of study, and of course geographic proximity. This structure will form a link between the GIS data library and the field data in the data management system, and will interface with the Agricultural Research Station (ARS) management needs via an internet map and database server.

Our site uses the Content Standards for Geospatial Metadata (Federal Geographic Data Committee, 1994) as a guide for the content and for of our metadata. Approximately 20 percent of the metadata elements from this standard are appropriate and used at our site. This information is currently stored in relational database tables and accessible for internal use and maintenance. For new and recent data layers, the required metadata elements are complete. Metadata for spatial data preceding the standard, although well documented may never have all of the required elements we currently collect.

One large GIS management task will be movement to a new data format used in Arc/Info version 8. Although movement of all data to this format will be time consuming, there will be many rewards, including a direct connection from the GIS software (Arc/Info) to the data management software (Access).

**Internet Access**: Prior to the advent of internet viewers, we supported machine and software independent views of our SGS Map Atlas through on-line map images. These map images could be viewed within the Colorado State University network using Unix-based non-GIS viewing tools, or transferred to remote locations via ftp (file transfer protocol) for viewing. This served primarily as a mechanism to facilitate communication and visualization for research.

These views are now supported and accessible through our internet site. An improvement to this current system is being developed which will provide customized views of the data and the database using an internet map server. The first set of functions to be implemented are the tasks involved in setting up a new study site with the ARS and tracking it through to completion. This includes views of the data needed to assess potential study sites, entering the GPS locations of the new study, and facilitating the yearly reports to the ARS. This uses the GIS database and the other SGS-LTER databases such as personnel and publications.

**Data Archive**: Purchased, SGS-automated, and project data are saved in duplicate on 8 mm tapes or CD in the original format, with the second copy stored in a separate location from the first. Data automated or developed in-house are stored in Arc/Info export format. The final products of project data are stored a similar manner. Final products are also stored together with all associated work files on 8 mm tape in triplicate: two copies for our site and one copy for the researcher. These are identified with the name of the project, date of completion and the researchers names.

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## Poster Titles

1. Rich Alward (not present)- *Grassland vegetation changes with nocturnal warming.*
2. Peter Adler- *Livestock exclusion increases the spatial heterogeneity of vegetation in the shortgrass steppe.*
3. John Barrett (not present)- *Nitrogen retention in semiarid ecosystems of the U.S. Great Plains.*
4. Dani-Ella Betz- *Dynamics of exotic species in the Pawnee National Grasslands.*
5. John Bradford- *Effects of climate, landuse, and soils on NDVI dynamics in the U. S. Great Plains.*
6. Stephen Del Grosso- *Modeling* $CH_4$ *oxidation in soils.*
7. Joe Eastman- *The Effects of* $CO_2$ *and landscape change using coupled plants and meteorological model.*
8. Debra Guenther- *Cattle use of prairie dog towns on the shortgrass steppe.*
9. Jeanine Junell- *Effects of prairie dog activities on the ground dwelling fauna of shortgrass steppe.*
10. Petra Lowe- *Effects of a Nitrogen and Competition gradient on the growth of an exotic invasive annual and a slow growing native perennial.*
11. Lixin Lu- *Implementation of a two-way interactive atmospheric and ecological modeling system and it's application to the central United States.*
12. Rebecca McCulley- *Sensitivity of grassland biogeochemical parameters across a naturally occurring precipitation gradient.*
13. Ken Murphy (not present)- *Regional analysis of plant tissue chemistry in the central grasslands of North America.*
14. Jennifer Roach (not present)- *Genetic structure of black-tailed prairie dog (Cynomys ludovicianus) populations in shortgrass steppe.*
15. Penny Sinton- *Carbon and nitrogen budget in irrigated corn, wheat fallow,, and native grasslands in Northern Colorado: A proposal.*
16. David Smith- *Primary production of summer-fallow winter wheat and native grasslands in Northern Colorado.*
17. Elizabeth Sulzman- *Factors influencing isotopes of soil* $CO_2$.
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# Journal Articles

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