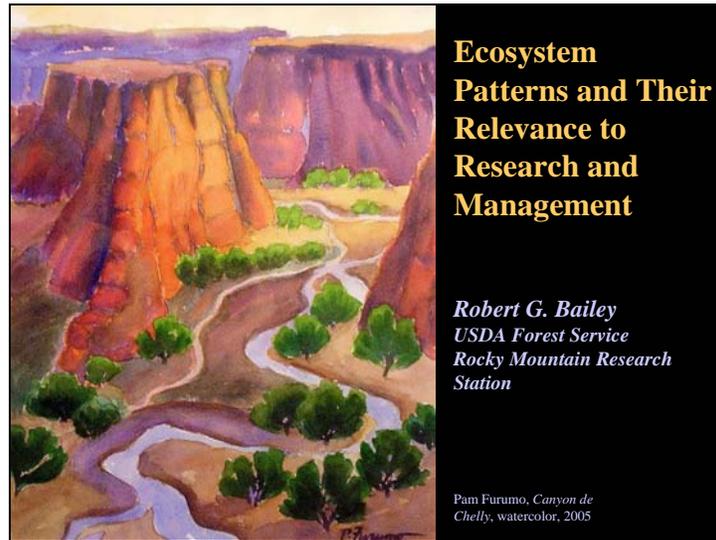


Slide 1



## **Ecosystem Patterns and Their Relevance to Research and Management**

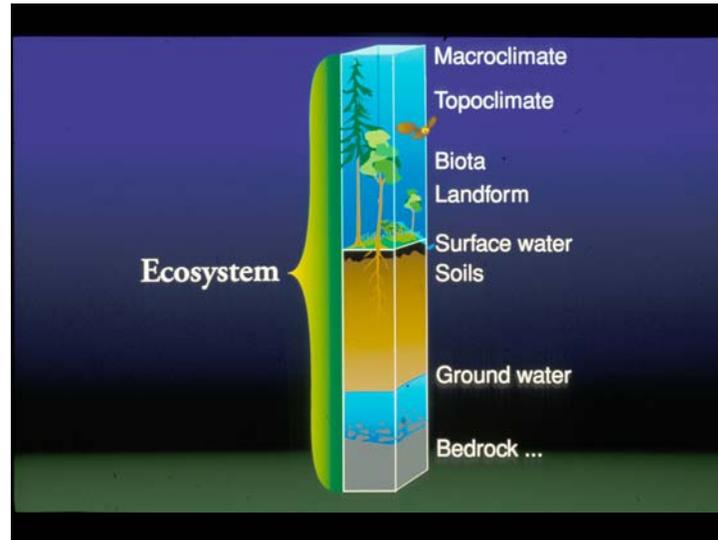
Robert G. Bailey

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**Abstract:** This presentation discusses the origins of ecosystem patterns from ecoregion to local scale. It describes how understanding these patterns can help scientists and managers in two ways. First, the local systems are shown within context of larger systems. This perspective can be applied in assessing the connections between action at one scale and effect at another, the spatial transferability of models, and the links between terrestrial and aquatic systems. Second, they are given information about the geographic patterns in ecosystems. Consequently, they are in a better position to design sampling networks, transfer knowledge, and analyze ecosystem diversity. The approach illustrates an alternative to single-phenomena and single-scale approaches and indicates the trend toward integration of factors in classifying and analyzing ecosystems at multiple scales. Thus it suggests new scientific directions for research and points the way for restructuring the Forest Service research programs.

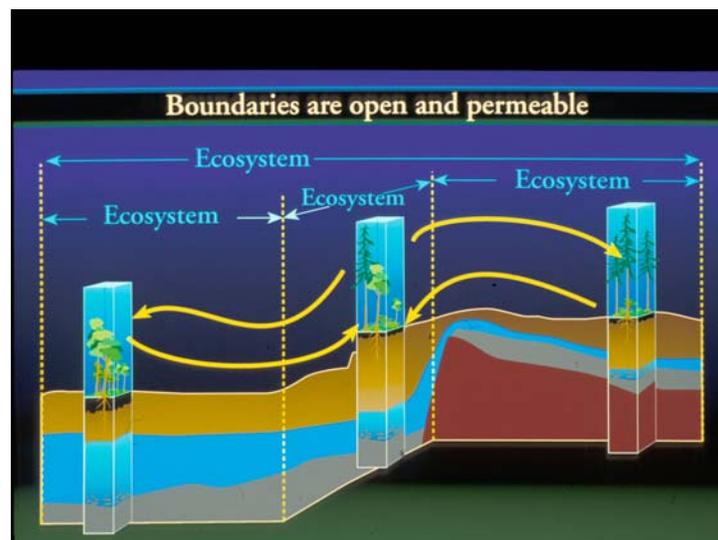
Slide 2



## Introduction

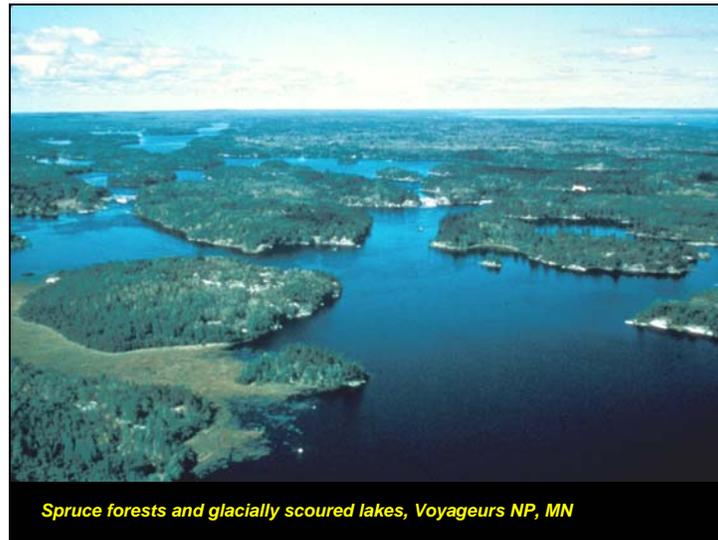
The public land-management agencies have been phasing into a new approach to land management. They are shifting from their focus on individual resources to a more holistic approach of managing *whole ecosystems*. In this approach the vertical structure is examined, which is how the components are integrated at a site. This is a replacement of the current reductionist, phenomena-based research by a *synthesis* approach.

Slide 3



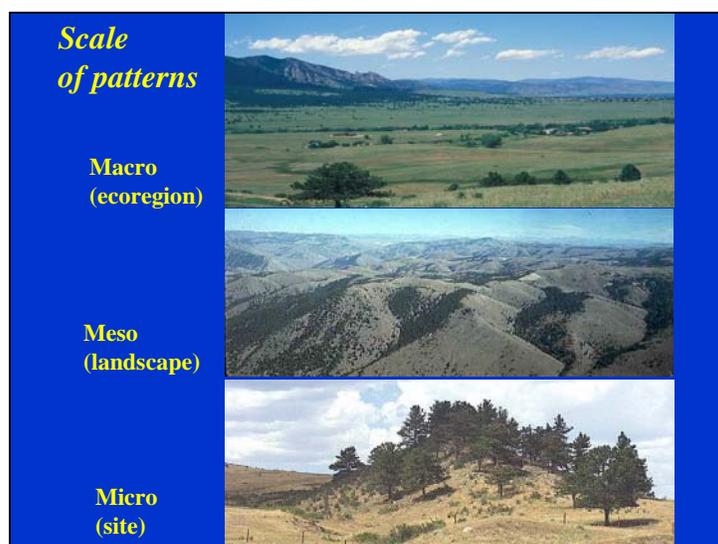
Ecosystems come in different scales that are nested within each other. The boundaries are open and permeable leading to interaction, or linkages, between systems. Problem: ecosystems related by geography are not necessarily related by taxonomic properties.

## Slide 4



Such as spruce forests and glacially scoured lakes, which equal a single system, linked by flows of water and nutrients through podzolized soils toward oligotrophic lakes. These are not terrestrial or aquatic, but geographical ecosystem units. Because of these linkages, modification of one system affects surrounding systems, sometime adversely. *Most research provides only knowledge of the vertical structure of the components.* There is need to consider horizontal structure, or connections between systems, because systems are linked to form larger systems. Alteration of larger systems may affect smaller. We must examine these relationships between systems of different scales in order to analyze the effects of management.

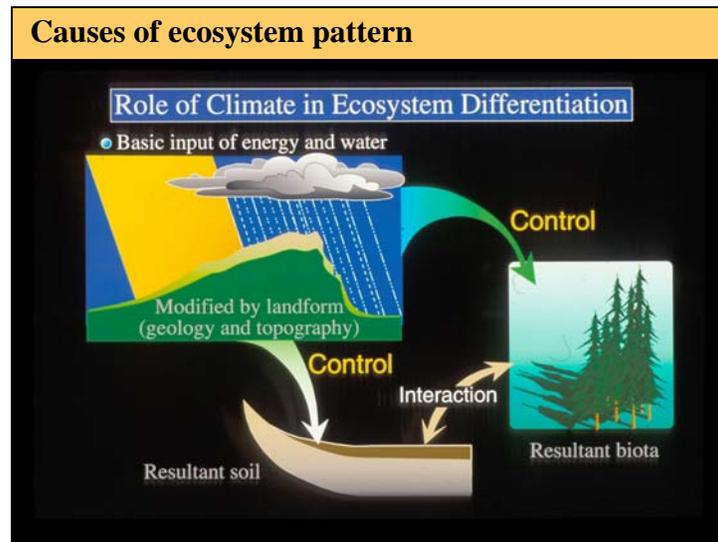
## Slide 5



*Scale of patterns*

Repeated patterns emerge at varying scales. For example, in the Boulder, CO area the rocky, forested Front Range slopes that rise abruptly from the grassy plains are the most prevalent patterns in that region. In the mountains, trees that respond to additional moisture are seen on north-facing slopes. Rock outcrops on the nearby Great Plains grasslands are repeatedly seen, accompanied by islands of trees and shrubs.

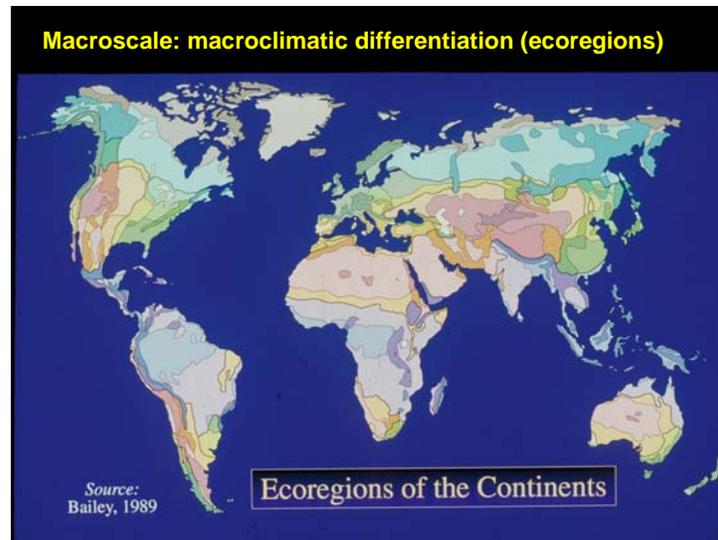
Slide 6



### *Causes of ecosystem pattern at varying scales*

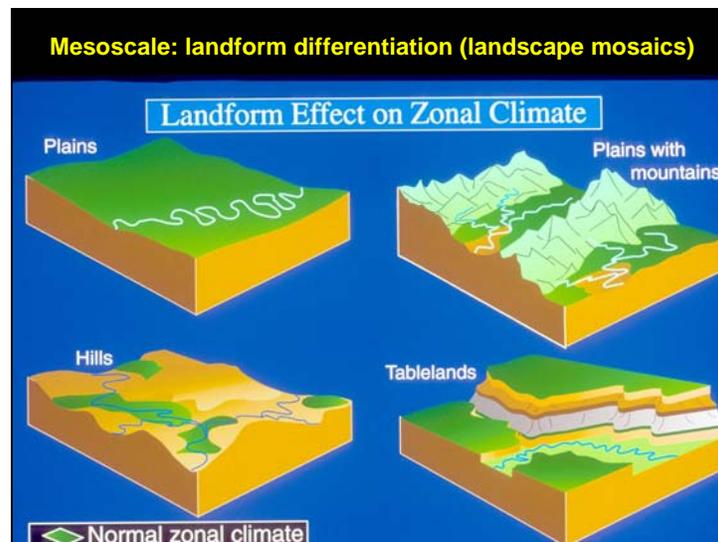
To delineate these patterns and to understand how and why they are distributed we must understand the *processes* of how they form. This is important in understanding their dynamics and how they respond to management. While the ecosystem concept implies equality among all the components of the system, all the components are not equally significant. Climate largely determines ecosystem boundaries. As it changes, the other components change in response.

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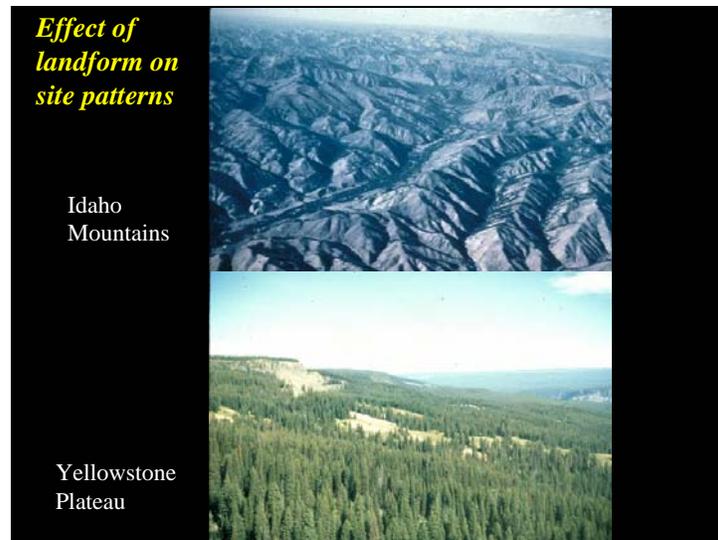
Controls over the climatic effect change with scale. At the macroscale, ecosystem patterns are controlled by the macroclimate (i.e., the climate that lies just beyond the local modifying irregularities of landform and vegetation). The effects of latitude, continental position, and elevation combine to form the world's ecoclimatic zones, also known as *ecoregions*.

Slide 8



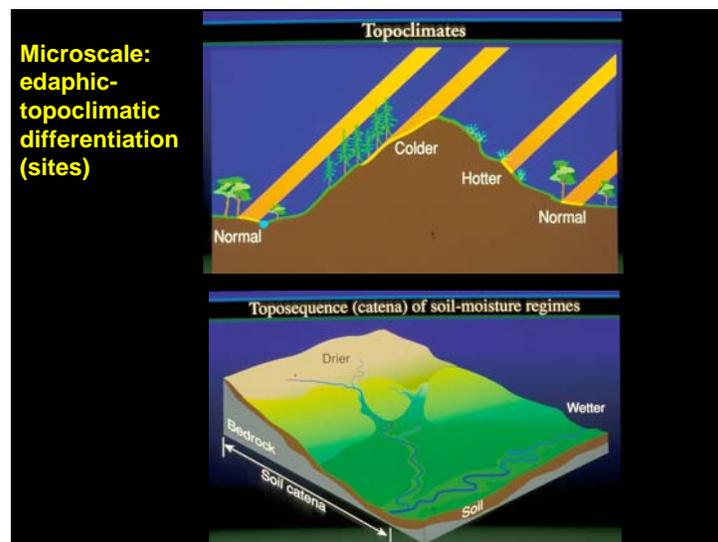
On a mesoscale within the same macroclimate, we commonly find several broad-scale landform patterns that break up the zonal pattern. Hamond's landform classification (based on surface geometry) illustrates the results of this effect on zonal climate and provide a basis for further differentiation of ecosystems, known as *landscape mosaics*.

Slide 9



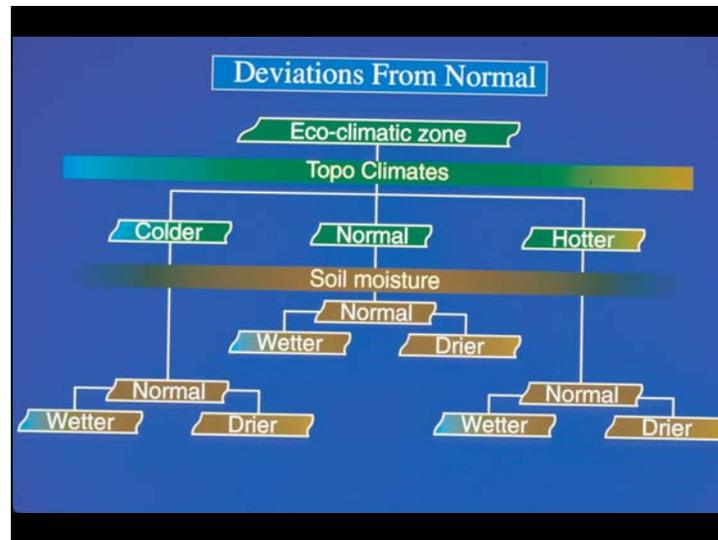
According to the way it breaks up the zonal climate, a landform unit consists of different ecosystem patterns. For example, the Idaho Mountains (top) and Yellowstone Plateau are both highlands in a temperate steppe climate. This image shows how these different landforms in the same climate affect site patterns.

Slide 10



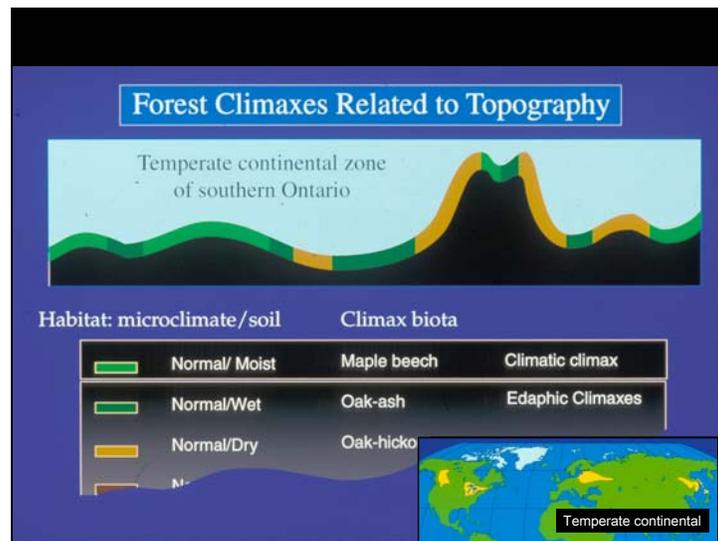
Local variation in topography will cause microscale variations in the amount of solar radiation received, create topoclimates, and affect the amount of soil moisture. These variations will subsequently affect the biota, creating ecosystem *sites* as subdivisions of a larger zone.

Slide 11



This diagram shows how topography, even in areas of uniform macroclimate, leads to differences in local climate and soil moisture conditions.

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Here is an example of the patterns of sites formed by edaphic-topoclimatic differentiation in the temperate continental zone of southern Ontario, which also extends south into the northeastern US.

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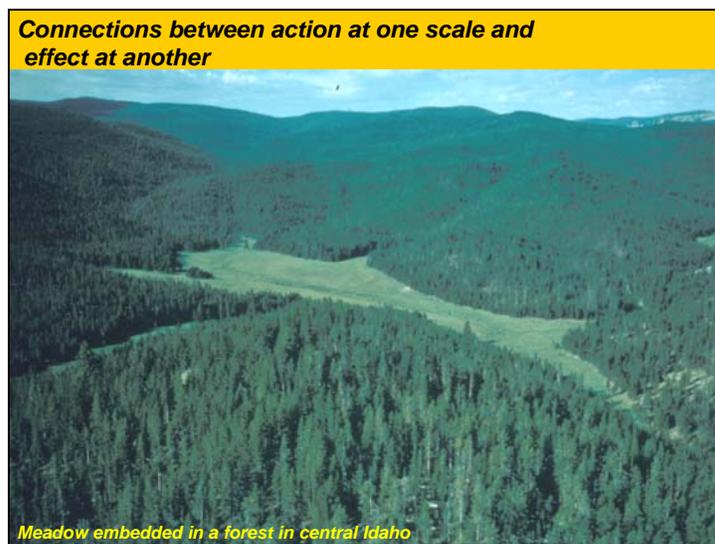
## Applications

- Local systems (sites) are seen within context of larger system

### Applications

There are many applications of the study of ecosystem patterns, such as research and management. Ecosystem analysis must be performed at multiple levels: local (site), and groups of geographically related sites known as landscapes or ecoregions. The significance of multi-level analysis is: First, *local systems (sites) are seen within the context of the larger system.*

Slide 14



### ***Connections between action at one scale and effect at another***

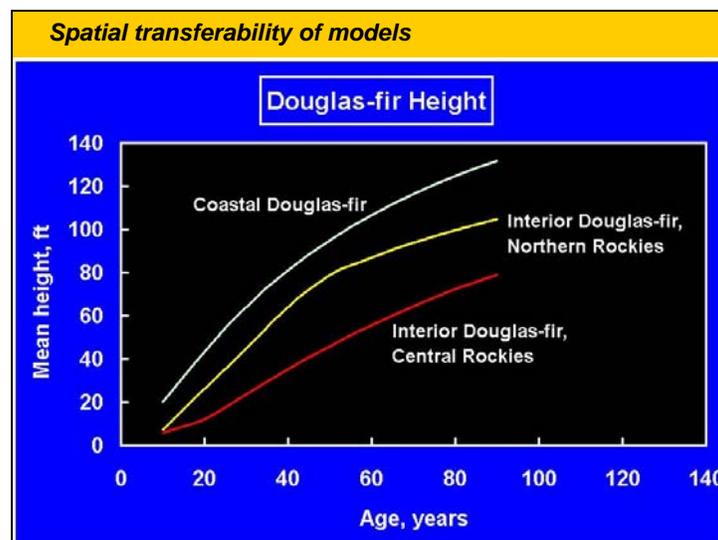
This perspective can be applied in assessing the connections between action at one scale and effect at another. For example, logging on upper slopes of an ecological unit may affect downstream riparian and meadow habitats.

Slide 15



It allows one to understand the interaction between sites. *Processes emerge* that were not evident at the site level. An example is a snow-forest landscape that includes dark conifers that cause snow to melt faster than either a wholly snow-covered or a wholly forested basin. Landscapes function differently as a whole than would have been predicted by analysis of the individual elements (cf., Marston 2006).

Slide 16



### *Spatial transferability of models*

Predictive models differ between larger systems. The same type of forest growing in different ecoregions will occur in a different position in the landscape and have different productivity. For example, this graph shows that the height-age ratio of Douglas-fir varies in different climatically-defined ecoregions. The ecoregion determines which ratio to apply to predict forest yield. This is important, because if a planner selects the wrong

ratio, yield predictions and the forest plans upon which they are based will be wrong. The ecoregion map is helpful in identifying the geographic extent over which results from site-specific studies (such as growth and yield models) can be reliably extended. Thus the map identifies areas for the *spatial transferability of models*.

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## Magnitude of the error in applying the wrong model

Huang, S; Prince, D; Titus, S.J. (2000) Development of ecoregion-based height-diameter models for white spruce in boreal forests. *Forest Ecology and Management* 129: 125-141

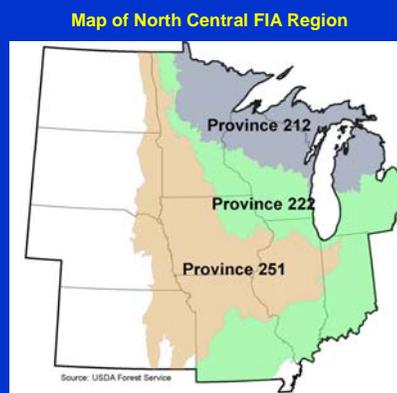
- **Overestimation: 1% and 29%**
- **Underestimation: 2% and 22%**

In Canada, studies have found that the height-diameter models of white spruce were different among different ecoregions. Incorrectly applying a height-diameter model fitted from one ecoregion to different ecoregions resulted in overestimation between 1% and 29%, or underestimation between 2% and 22%.

Slide 18

**“... need to calibrate growth models by ecoregion rather than states or FIA regions”**

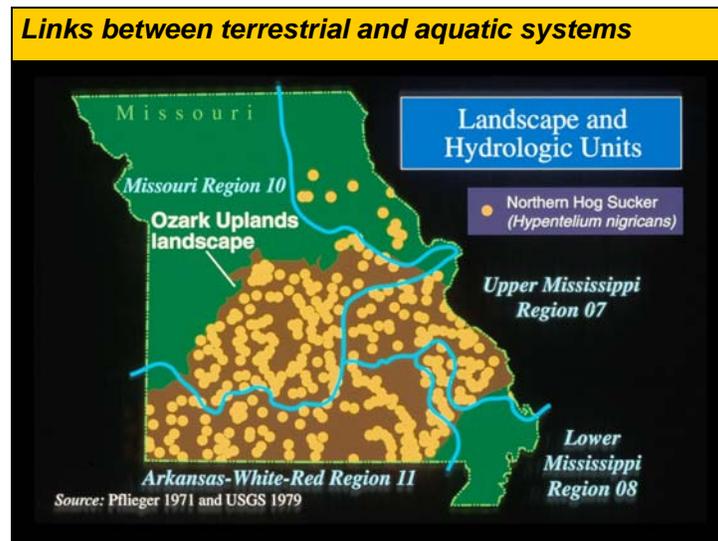
Ron McRoberts, NCRS



Note: This issue has been documented by Hansen (2002)

However, there is another, more compelling example. Each of five regional Forest Inventory & Analysis (FIA) programs has developed its own set of volume models, and the models have been calibrated for regions defined by political boundaries corresponding to groups of states rather than ecological boundaries. Further, the regional models sometime bear little resemblance to each other. The same tree shifted a mile in various directions to move from southwest Ohio (Northeastern FIA) to southeast Indiana (North Central FIA) to northern Kentucky (Southern FIA) could have quite different model-based estimates of volume.

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### ***Links between terrestrial and aquatic systems***

Streams are dependent on the terrestrial system in which they are embedded. They therefore have many characteristics in common, including biota. By delineation of areas with similar climatic characteristics makes it possible to *identify areas within watersheds with similar aquatic environments*. A good example is the distribution of fish in the Ozark Uplands which covers several watersheds.

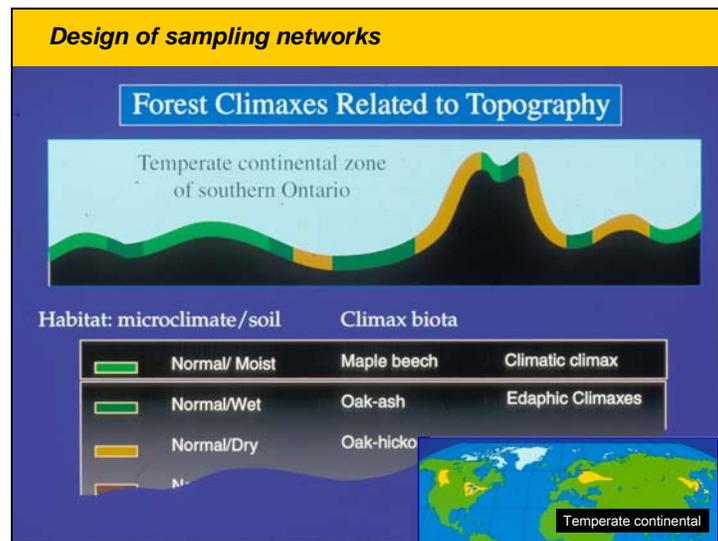
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## Applications

- Local systems (sites) are seen within context of larger system
- Information about geographic patterns in ecosystems

Second, this analysis also provides *information about the geographic patterns in ecosystems.*

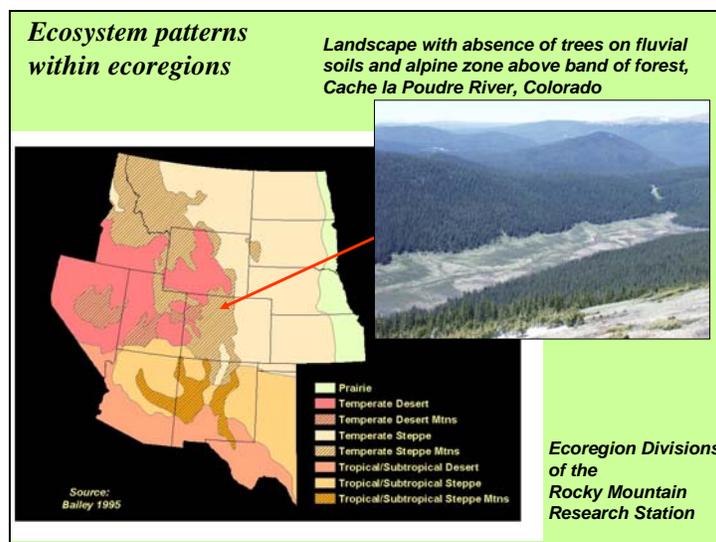
Slide 21



### ***Design of sampling networks***

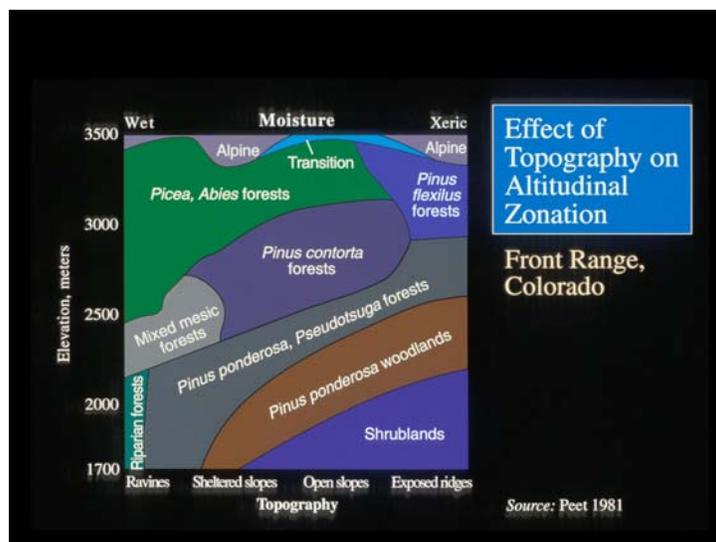
Users are, thus, in a position to design efficient sampling networks. As we have seen, ecosystems recur in predictable patterns within an ecoregion. Data from representative sampled sites can be applied to analogous (unsampled) sites with a high degree of reliability

Slide 22



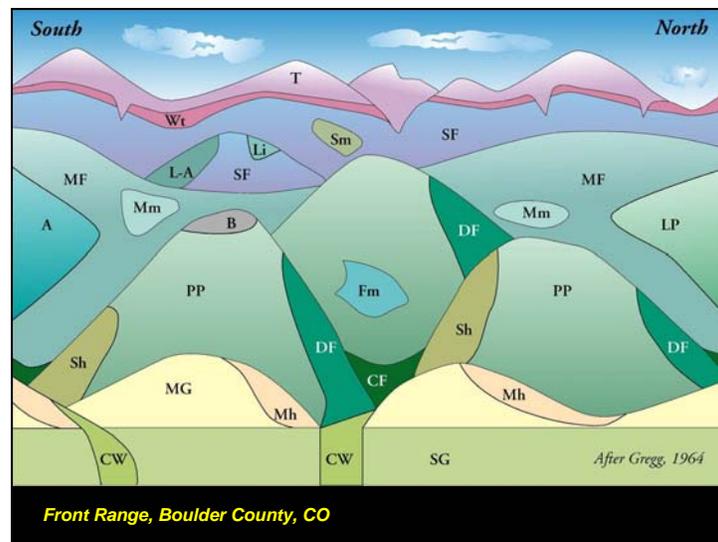
Here is another example from the Rocky Mountain Research Station. The inset photo shows ecosystem patterns within the Temperate Steppe Mountains ecoregion. This ecoregion, like all ecoregions, is a climatic region within which specific plant successions occur upon specific landform positions. The most probable vegetation growing on a site within an ecoregion can be *predicted* from landform information if one know the vegetation-landform relationships in a particular ecoregion.

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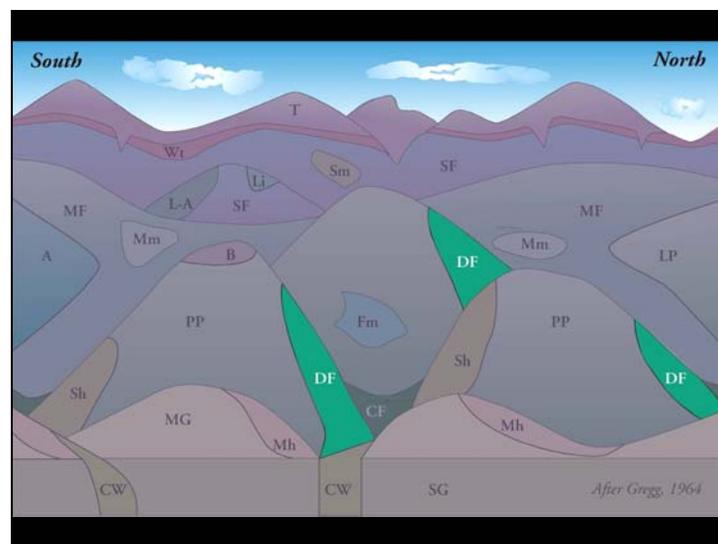
For example, Douglas-fir (*Pseudotsuga*) forests occur on moist, mid-elevation sites within the Front Range of Colorado. This figure shows the relationships between elevation-topography and climax plant communities.

Slide 24



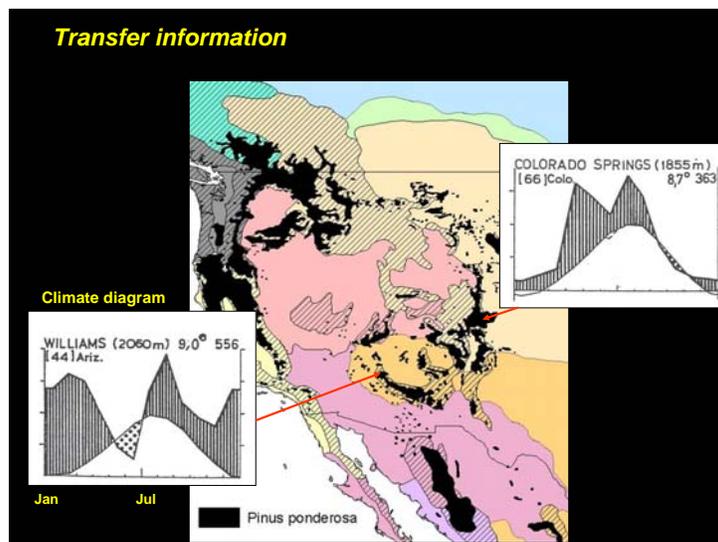
This diagram, looking west, shows the relationships between landform and vegetation types of the Front Range in Boulder County, Colorado. (Lands of the Roosevelt National Forest encompass the lower slopes while the upper slopes are located in Rocky Mountain National Park. Note: DF = Douglas-fir; PP = Ponderosa pine; LP = Lodgepole pine; SF = spruce-fir forest, etc.)

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Understanding these relationships, vertically and horizontally, within an ecoregion delineation enables one to transfer knowledge from research sites (or inventory plot) to like sites within the same ecoregion. In fact, surveys involving comprehensive sampling efforts will more accurately characterize unmonitored sites (plots) when samples are stratified according to ecologically similar areas such as ecoregions (O'Brien 1996).

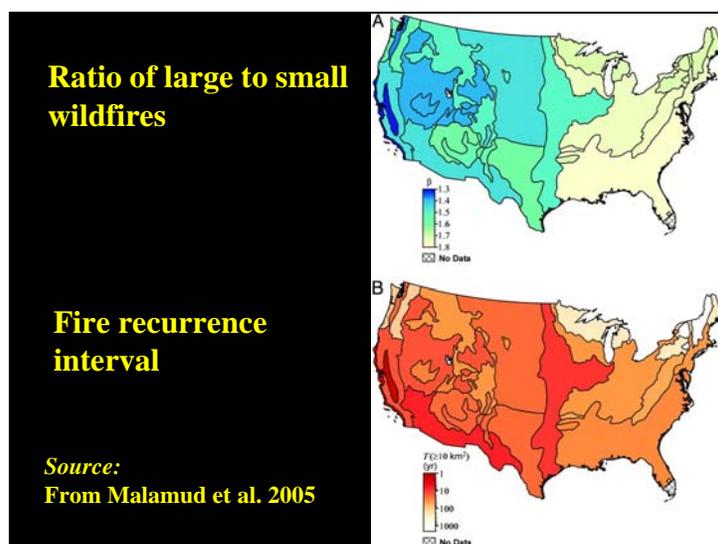
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### **Transfer information**

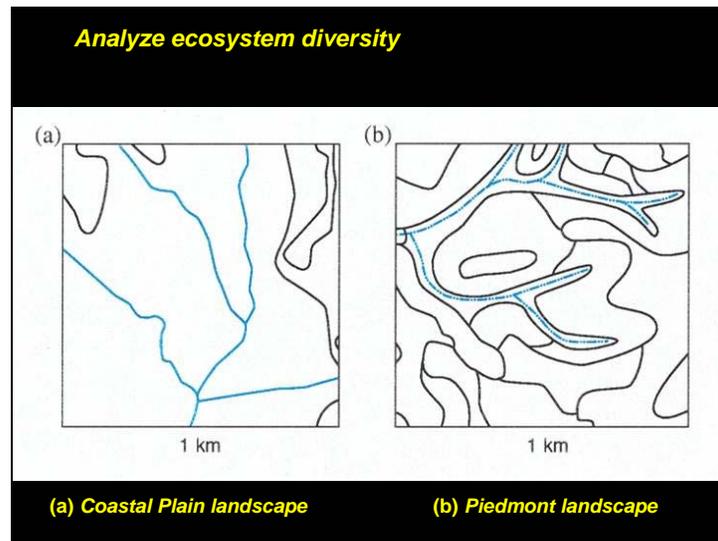
Ecoregions show areas that are analogous with respect to ecological conditions. This makes it possible to transfer knowledge gained from one part of a continent to another and from one continent for application in another. However, this approach should be used with **caution**. Because of compensating factors, the same forest type can occur in different ecoregion divisions. It has no regional alliance. For example, ponderosa pine forest occurs in the northern Rockies and the southwest. This does not imply that the climate, topography, soil and fire regime are necessarily the same. (Note climate diagram for Williams, AZ has a late spring drought shown by dot pattern. Colorado Springs is moist throughout the year.)

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This distinction is important because some ecoregions have a tendency for large wildfires; the ratio of large to small wildfires decreases from east to west. Also, fire recurrence interval differs markedly between ecoregions with greater frequency in the West. This suggests that the results of these studies can be used to assess burn probability across the nation to identify areas with the high risk. This could help government agencies better plan for wildfire hazards. They can also be used as a baseline from which to assess natural fire regimes, which can be used to abate the threat of fire exclusion and restore fire-adapted ecosystems.

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***Analyze ecosystem diversity***

Maps of landscape mosaics reveal the relative diversity of ecosystems. These maps are examples of ecosystem diversity from North Carolina as reflected in soil boundaries.

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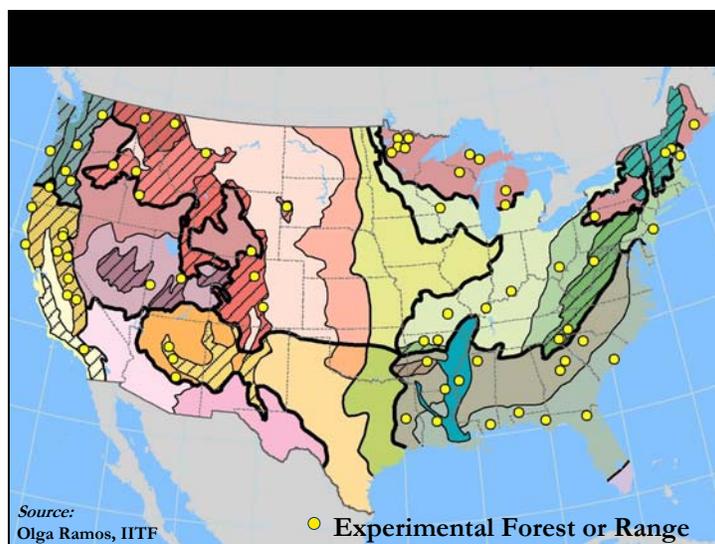
## Significance to Forest Service research

Ecosystem hierarchy	Research hierarchy
Ecoregion	Research Station (multi-ecoregions)
Landscape mosaic	Experimental Forest/Range, Watershed
Site	FIA plot, LTER site, Research Natural Area

### Significance to Forest Service research

It is important to link the ecosystem hierarchy with the Forest Service research hierarchy. In so doing, research structures and ecosystem hierarchies correlate such that research information, mapping levels, and research studies work well together. Comparison of research structures and ecosystem levels can identify gaps in the research network.

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At the ecoregional scale, comparison of existing research locations can be compared with ecoregion maps to identify underrepresented regions or gaps in the network. The experimental forests or ranges occur in only 26 of 52 ecoregion provinces (Lugo et al. 2006). Several ecoregions have no research sites while others have multiple sites. The greatest number (14) falls within the Laurentian mixed forest ecoregion of the Lake States and Northeast.

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### ***Restructuring FS Research Programs***

- **Move from single- to multiple-scales**
- **Replacement of research on plots and stands to mosaics of ecosystems (landscapes and ecoregions)**
- **And from streams and lakes to integrated terrestrial-aquatic systems (i.e., geographical ecosystems)**

#### ***Restructuring FS research programs***

The approach to the study of ecosystem patterns illustrates an alternative to single-phenomena and single-scale approaches and indicates the trend toward integration of factors in classifying and analyzing ecosystems at multiple scales. Thus it suggest new scientific directions for research and points the way for restructuring FS research programs. To address critical ecological issues, it is essential to move from the traditional single-scale management and research on plots and stands to mosaics of ecosystems (landscapes and ecoregions) and from streams and lakes to integrated terrestrial-aquatic systems (i.e., geographical ecosystems).

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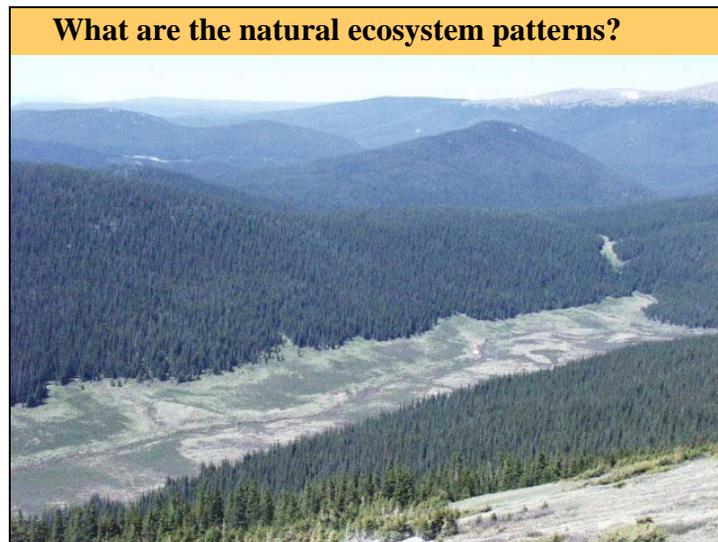
### ***Some Research Questions***

1. **What are the natural ecosystem patterns in a particular ecoregion?**
2. **What are the effects of climatic variation on ecoregional patterns and boundaries?**
3. **What are the relationships between vegetation and landform in different ecoregions?**

***Some Research Questions***

These studies reveal useful applications of ecosystem patterns. However, there remain a number of relevant research questions associated with these patterns, including: First, what are the natural ecosystem patterns in a particular ecoregion? Second, what are the effects of climatic variation on ecoregional patterns and boundaries? And, third, what are the relationships between vegetation and landform in different ecoregions?

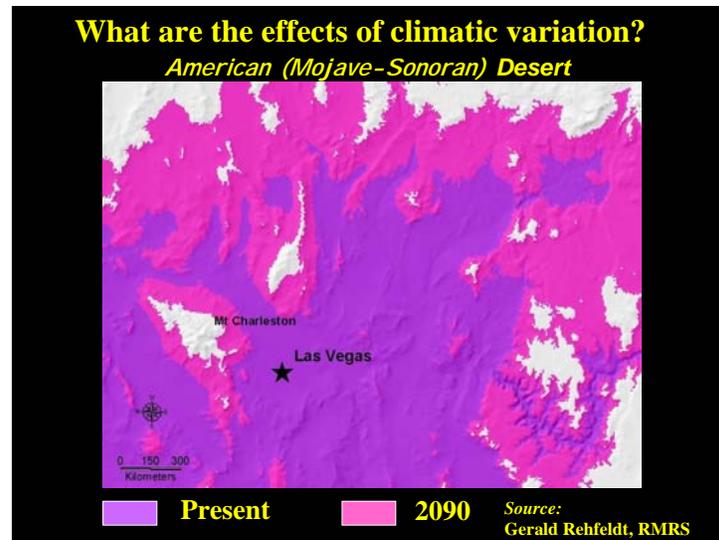
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***What are the natural ecosystem patterns?***

Historically, a high level of landscape heterogeneity was caused by natural disturbance and environmental gradients. Now, however, many forest landscapes appear to have been *fragmented* due to management activities such as timber harvesting and road construction. To understand the severity of this fragmentation, the nature and causes of the spatial patterns that would have existed in the absence of such activities should be considered. *This provides insight into forest conditions that can be attained and perpetuated* (Knight and Reiners 2000). (This is a landscape illustrating the absence of trees on fluvial soils in the valley and alpine zone above a narrow band of forest dominated by spruce and subalpine fir.)

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***What are the effects of climatic variation?***

Anthropogenic and climatic change could yield ecoregions that are much different, or less useful, after many years. Therefore, temporal variability is an important research issue. Jerry Rehfeldt of the Rocky Mountain Research Station has predicted the potential distribution of the American (Mojave-Sonoran) Desert ecoregion under the future climate scenario produced by the IS92a scenario of the Global Climate Model, with about 5 degrees F warming and 50 percent increase in precipitation. Despite the percentage increase in ppt, the amount of rainfall fails to keep pace with the increase in temperature with the result that the climate increases in aridity. *Sites should be placed where they can detect change.*

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**What are the relationships between vegetation and landform?**

Ecoregion	Topoclimate		
	Hotter	Normal	Colder
1	P		
2	P		P
3	P		P
4	A	P	P
5	A		A,P
6	C		A,P
7			C,A

P = white spruce; A = sugar maple; C = shagbark hickory  
 From Burger (1976)

***What are the relationships between vegetation and landform?***

The relationships between vegetation and landform position changes from ecoregion to ecoregion, reflecting the effect of the macroclimate. A species occupies different positions in the landscape. For the same soil moisture condition but with different topoclimates tree species change their positions in different regions. With these changes, related changes occur in the vigor of other tree species, ecosystem productivity, etc. Knowledge of these differences is important for extending results of research and management experience, and for designing sampling networks. *These relationships have been extensively studied in some regions but, unfortunately, not in others.*

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**Acknowledgments:**

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Forest Inventory and Analysis

Jerry Rehfeldt (retired)  
Rocky Mountain Research Station

**Acknowledgments:**

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Slide 37

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