MONTANA STATE UNIVERSITY

Ecological effects of weather modificiation, Bridger Range area, Montana : relationships of soil, vegetation and microclimate
by Bruce Albert Buchanan

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Crop and Soil Science
Montana State University
© Copyright by Bruce Albert Buchanan (1972)

Abstract:
Ecological effects of weather modification were studied for two years near Bozeman, Montana in a lodgepole pine zone characterized by open meadow, ecotone (transition), and forest. A program to study the effects of seeding winter orographic clouds on precipitation is being conducted by Montana State University in the Bridget Range area. The objective of this study was to determine effects of winter precipitation on factors that maintain the vegetational patterns. Data was collected along transects that extended across the vegetational types and a gradient of snow depth.

Factors correlated with snow depth in the meadow include: soil pH (-), soil phosphorus (+), frequency of Festuca, Lupinus, Achillea, Danthonia, Dodecatheon, and Myosotis (all -), and frequency of Viola, PhIeum, Stipa, Bromus, and native lodgepole pine seedlings (all +). Factors correlated with snow depth in the ecotone include: soil pH (-), soil phosphorus (+), frequency of Lupinus, Danthonia, Dodecatheon, and Myosotis (all -), frequency of Erythronium. Viola, Claytonia, Phleum, Stipa, and Bromus (all +), and ground level summer precipitation (-). Factors correlated with snow depth in the forest includes soil calcium (+), frequency of Arnica, and lodgepole pine greater than 2 m tall (both -), frequency of Achillea and Koeleria (both +), and ground level summer precipitation (+).

Soil profile descriptions, plant frequency, and microclimatic measurements indicated that the forest community is discrete and areas classified as ecotone are relic meadows. Trees are presently invading meadows. The rate of this enchroachment will likely increase with increases in winter precipitation, as suggested by the correlation between survival of planted lodgepole pine seedlings and maximum snow depth measured in the spring of 1970. Factors that maintain vegetation patterns and that could be affected by weather modification include growing season length and the availability of nutrients and soil moisture.

Available soil moisture was emphasized in this study and was measured with neutron scatter equipment periodically from September 1968 thru September 1970. High soil moisture stress occurred sooner in meadow than in ecotone or forest. Deep snow tended to delay the onset of high soil moisture stress. An important conclusion of this study was that late season soil moisture availability was positively correlated with snow depth. This relationship of snow depth with soil moisture explains, in part, the correlation between survival of planted lodgepole pine seedlings and snow depth.

ECOLOGICAL EFFECTS OF WEATHER MODIFICATION, BRIDGER RANGE AREA, MONTANA: RELATIONSHIPS OF SOIL, VEGETATION AND MICROCLIMATE

by

BRUCE ALBERT BUCHANAN

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Crop and Soil Science

Approved:

Kurt C Feltner
Head, Major Department

Gerald A. Nielsen
Chairman, Examining Committee

K Goering
Graduate Dean

MONTANA STATE UNIVERSITY
Bozeman, Montana

March, 1972

ACKNOWLEDGEMENTS

I wish to express my appreciation to Dr. Gerald A. Nielsen for his continual assistance and willingness to help during the highs and lows of this project.

My gratitude is extended to the committee members, Dr. A. Hayden Ferguson, Dr. Richard E. Lund, Dr. John C. Wright, and especially to Dr. James R. Sims.

Numerous others have been helpful during this project; some that deserve special recognition are: Richard J. Alvis, USDA Forest Service, for his work on the reconnaissance soil survey; Dr. James E. Loten, USDA, IFRES, for his help with the lodgepole pine planting study; Dr. Theordore W. Weaver from the Botany Department for his assistance, comments, and cooperation; Dr. Arlin B. Super, Dr. Val L. Mitchell, and others from the Earth Science Department for their assistance and cooperation; Mr. Robert Berland for his friendship, côffee, and warm HOME on the Bangtail; the many graduate students who contributed to my education; the work-study students for their cooperation and especially to one, Mr. Robert H. Beck, whose enthusiasm, ideas, and efforts made much of the data collection possible. To those I have forgotten, my apologies are extended.

A special personal thanks is deserved by my mother and mother- and father-in-law for their support. My deepest and most deserving gratitude is to my wife and family for their patience and understanding.

This research was in part supported by two National Science Foundation Grants, GB 7302 and GB 20960.

TABLE OF CONTENTS

TABLE OF CONTENTS
Concluded

LIST OF TABLES

LIST OF TABLES
Continued

APPENDIX TABLES

LIST OF APPENDIX TABLES
Concluded

LIST OF FIGURES AND PLATE

LIST OF APPENDIX FIGURES
Concluded

ABSTRACT

Ecological effects of weather modification were studied for two years near Bozeman, Montana in a lodgepole pine zone characterized by open meadow, ecotone (transition), and forest. A program to study the effects of seeding winter orographic clouds on precipitation is being conducted by Montana State University in the Bridger Range area. The objective of this study was to determine effects of winter precipitation on factors that maintain the vegetational patterns. Data was collected along transects that extended across the vegetational types and a gradient of snow depth.

Factors correlated with snow depth in the meadow include: soil pH (-), soil phosphorus (+), frequency of Festuca, Lupinus, Achillea, Danthonia, Dodecatheon, and Myosotis (all -), and frequency of Viola, Phleum, Stipa, Bromus, and native lodgepole pine seedlings (all +). Factors correlated with snow depth in the ecotone include: soil pH (-), soil phosphorus (+), frequency of Lupinus, Danthonia, Dodecatheon, and Myosotis (all -), frequency of Erythronium, Viola, Claytonia, Phleum, Stipa, and Bromus (all +), and ground level summer precipitation (-). Factors correlated with snow depth in the forest includes soil calcium (+), frequency of Arnica, and lodgepole pine greater than 2 m tall (both -), frequency of Achillea and Koeleria (both +), and ground level summer precipitation (+).

Soil profile descriptions, plant frequency, and microclimatic measurements indicated that the forest community is discrete and areas classified as ecotone are relic meadows. Trees are presently invading meadows. The rate of this enchroachment will likely increase with increases in winter precipitation, as suggested by the correlation between survival of planted lodgepole pine seedlings and maximum snow depth measured in the spring of 1970. Factors that maintain vegetation patterns and that could be affected by weather modification include growing season length and the availability of nutrients and soil moisture.

Available soil moisture was emphasized in this study and was measured with neutron scatter equipment periodically from September 1968 thru September 1970. High soil moisture stress occurred sooner in meadow than in ecotone or forest. Deep snow tended to delay the onset of high soil moisture stress. An important conclusion of this study was that late season soil moisture availability was positively correlated with snow depth. This relationship of snow depth with soil moisture explains, in part, the correlation between survival of planted lodgepole pine seedlings and snow depth.

INTRODUCTION

Man, like any other organism, has a relationship with his environment; it can be one of balance or one of imbalance. The decision is unique to man most of the time, and imbalances are often the unforeseen consequences affecting environmental quality. These consequences are thought by Cooper (1970) to be a result of man's increasing technological ability to interfere constructively in natural ecological processes.

A technological ability that was recognized by man in the early thirties is artificial modification of weather (Fleagle 1969). Now, it is an accomplished fact that cloud seeding can produce an increase in rain and snow from orographic clouds (Dennis 1970). Because weather modification could be responsible for unforeseen consequences, this study was initiated. Effects of weather modification could influence: 1) law and legislation, 2) human behavior, 3) international affairs, and 4) biological processes. This last possibility was the subject of this study.

The objective was to determine effects of an increase in winter precipitation on factors that maintain plant communities in the target area. It was hypothesized that for weather modification to bring about community change, it must significantly affect the maintaining factors. Measurements of available soil moisture and their relationship with snow depth was emphasized.

Research began during July 1968 and continued through September 1970 and was in part supported by two National Science Foundation Grants, GB 7302 and GB 20960.

Plate 1. Krummholz communities in the Bangtail study area. Photograph by Lyn Taylor, Earth Science Dept., M.S.U., May 29, 1969. Direction of prevailing wind is from center right (west) to lower left (east). Approximate slope is 7%, aspect NE, and elevation 2400 m.

Snow drifts associated with the trees may persist until July 15, nearly two months longer than snow in the open meadow. These krummholz communities are considered beneficial for late water yield and as recreational sites. They also provide aesthetic diversity not provided by solid forest (background) or vast meadow. Tree invasion is apparent in several areas of the meadow.

STUDY AREA

The Bridger Range is the target area of a current weather modification study at Montana State University. The Bangtail Ridge, located in the Bridger area, was selected for this study because it may be affected by the modification of winter precipitation.

LOCATION - The approximate center of the ridge (Bangtail Ranger Station) is located 24 km (15 mi) northeast of Bozeman, Montana, and 11 km (7 mi) due east of the Bridger Range. It extends along a northwest axis for approximately 11 km (7 mi) and reaches a maximum elevation of 2434 m (7982 ft).

An aerial mosaic made from zerox copies of aerial photographs is presented in Fig. 1 to show the complex pattern of vegetation. Generally, the light colored areas are meadows and the dark areas, forest. The areas associated with the forest-meadow interface and those appearing as a forest-meadow complex are thought to be transitional areas. These areas are referred to throughout the paper as the ecotone.

The name for this community follows the concept of Odum (1959) who describes the ecotone as a tension belt narrower than the adjoining communities commonly containing organisms from each and some that are characteristic of and often restricted to the community.

Also included in Fig. 1 are study site locations, roads and trails, and the 2194 m (7200 ft) and 2316 m (7600 ft) contours.