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AN ECOLOGICAL STUDY OF ASPEN FOREST COMMUNITIES IN THE CENTRAL ROCKY MOUNTAIN REGION

A Basic Research Proposal

submitted by

The Institute of Environmental Biological Research

University of Utah

to

National Science Foundation

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Desired Starting Date:	May 1, 1966
Alternate:	June 1, 1966

Time Requested:	Four years

This proposal has not been submitted elsewhere.

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I. ABSTRACT

A review of the literature pertaining to quaking aspen (*Populus tremuloides* Michaux) indicates that the basic ecology of the species in Western America is poorly understood. The need for a thorough knowledge of aspen ecology is made urgent by the ever increasing importance of this forest type for watershed cover, timber, big game habitat, recreation, and domestic livestock range.

It is the objective of this study to make a thorough study of the basic ecology of the aspen forest ecosystem as it exists in Western America. It is proposed that the study extend over a four year period. During that period, aspen forests will be studied throughout the Central Rocky Mountain Region (here considered to include all or part of the following states: Idaho, Wyoming, Nevada, Utah, Colorado and Arizona). Research activities will be concentrated on the following aspects of the basic problem:

1. A quantitative analysis of the relationship of aspen site quality to physical and chemical characteristics of the soil profile and to topographic and climatic variables.

2. A study of the response of major understory species of aspen communities along gradients of soil moisture, mineral nutrients and temperature.

3. A study of successional dynamics in aspen forests.

4. Development of a "total site" classification system for aspen communities of the Central Rockies that will permit one to accurately predict site quality for aspen, production of understory vegetation and possible successional trends for any given stand.

II. OBJECTIVES AND SIGNIFICANCE

Baker (1925) reports that quaking aspen forests cover an aggregate of approximately 4,000,000 acres in the Central Rocky Mountain area of western America. A major portion of that acreage is confined to the states of Colorado and Utah, but Arizona, Idaho, Nevada, New Mexico and Wyoming also support extensive stands of aspen.

Although never of as great an importance for timber as in the upper Midwest, aspen is, nevertheless, of prime importance as a forest type in western America, particularly in the Central Rocky Mountain Region. The importance of this forest type is primarily related to the multitude of uses to which it is put. Aspen has always been important as big game habitat, and has since the coming of white man, become important as "summer" range for livestock. Aspen has also come to be recognized as excellent watershed cover and as a choice recreational type. Advances in wood technology have brought the species into recent prominence as a timber tree. It is thus with good reason that Western foresters have come to refer to aspen forests as "a truly multiple use type" (Julander, Lewis and Olson, 1965). Without doubt the type holds a position of importance in the economy of forested lands of the Central Rocky Mountain Region that is far out of proportion to the actual area covered.

In view of the relative importance of aspen, it is surprising that the ecology of the species in the Mountain West has received so little attention. Numerous notes and peripheral studies consider individual facets of aspen ecology, but Baker's study (1925) is the sole attempt to interpret the general ecology of the aspen type in Western America. Even Baker's classical study largely ignores characteristics of the understory vegetation and details of the soil environment. Thus at the present time when new and often conflicting demands are being made on this forest type, the ecologist finds himself confronted with a bewildering array of ecological questions for which there are few, well-documented answers.

It is the overall objective of this study to collect basic ecological information pertaining to the aspen forest type of the Central Rocky Mountain Region. Specific objectives include the following:

1. Collection of vegetational composition and production data (of both tree and understory strata) from representative aspen communities throughout the region.
2. Identification of the major soil, topographic and climatic variables influencing site quality for aspen.
3. Compilation of autecological data (including response along important environmental gradients) for major understory species of the aspen forests.

4. Providing a better understanding of the dynamics of succession in various aspen communities.
5. Development of a "total site" classification system based on understory species that will permit one to predict site quality for trees, probable successional trends and understory production on any given site within the specified study area.

III. RELATION TO PRESENT STATE OF KNOWLEDGE

Although many workers have conducted studies in the quaking aspen type of the Mountain West, few have devoted much attention to the "over-all" ecology of aspen itself. Baker's (1925) paper is the only intensive consideration of the ecology of the species, although several other investigators have studied individual facets of aspen ecology. Sampson (1919) and Baker (1918) studied the influence of domestic grazers on aspen reproduction. Meinecke (1929) made a particularly interesting study of aspen diseases and includes many observations on the ecology of aspen. Age and height values for aspen growing in association with different understory types in Montana have been reported by Lynch (1955). A popularized account of aspen ecology in the West was published recently by Cottam (1963). Langenheim (1962) working in western Colorado and Ream (1963) in the Wasatch Mountains of Utah and Idaho drew general conclusions about the relative position of aspen in the environmental complex in their respective areas.

The most conspicuous deficiency in all of the foregoing studies lies in their failure to study the abiotic environment in detail. "Full profile" soil studies, for instance, have only been made by Lynch (1955), and that author has not analyzed the soil data in such a way as to provide a basis on which plant performance could be interpreted or predicted. Likewise a report of the influence of topographic position on the behavior of aspen has never appeared in the literature. A study of the literature dealing with aspen in the Rocky Mountains thus leads one to the conclusion that an environmental interpretation of aspen site classes based on tree height growth (see Baker 1925) is needed.

Perhaps the inadequacy of our present understanding of aspen ecology in western America is best demonstrated by the diversity of opinions concerning the successional status of the species. That aspen is successional on certain sites has never been questioned, but for almost half a century, western ecologists have debated the question of whether aspen is climax in certain specific areas. Fetherolf (1917), Reed (1952), Lynch (1955), Marr (1961), Langenheim (1962) and Julander, Lewis and Olson (1964) all consider aspen to be climax on some sites in the Rockies. Baker (1918,1925), Daubenmire (1943), Hall (1953), Oosting (1956), Hoff (1957), and Strothmann and Zasada (1957) are but a few of the many ecologists who prefer to interpret aspen as a successional type on all sites. Advocates of aspen as a climax type refer to extensive forests which support no conifer growth (Fetherolf 1917) and to the deep "aspen" soils which have developed there (Julander, Lewis and Olson 1965) as evidence that such sites are unfavorable for conifers. Those viewing aspen as a successional type consider such cases of apparent stability as being related to a simple absence of seed source for conifers (Baker 1918 and Hall 1953). Although the basic consideration in question (i.e. whether conifers can displace aspen on all sites) could be tested experimentally, such tests have never been made.

A thorough understanding of the degree of stability of aspen communities is essential if the overall ecology of this forest type is to be unravelled. It is thus important that the successional status of aspen be more thoroughly investigated.

Maintenance of the aspen type even in the absence of competition from conifers is not always achieved. Overgrazing by livestock or big game in over-mature stands or in stands ravaged by disease or insects may result in elimination of aspen from the site. Presently in the Mountain West there are thousands of acres of aspen severely thinned by age or disease in which there is no reproduction to replace the dying trees. Adverse effects of livestock grazing on aspen reproduction have been documented in the literature (Baker 1918 and Sampson 1919). Likewise, studies now being conducted by Dr. Odell Julander of the U.S. Forest Service indicate that big game also severely damage aspen reproduction.

The influence which genetic diversity in aspen will have on attempts to decipher the species ecology is unknown at the present time. That the species is genetically diverse has been established by many workers (Baker 1921, Pauley 1949, Cottam 1954, Marr 1961, Egeberg 1963, Garret 1964 and Strain 1964). Personal field observations indicate that genetic diversity is widespread and striking and that it affects susceptibility to disease, growth characteristics and longevity. Since genetic relations seem to be so important, they should be studied throughout the range of aspen. In the study here proposed, clonal characteristics and variation within each stand will be described and photographed and herbarium specimens collected. Clones will also be scored according to the degree to which they are infected by major diseases. The proposed study will not, however, evaluate the problem of genetic diversity in sufficient depth or breadth to satisfactorily solve the fundamental problems involved.

Compositional characteristics of the understory in aspen forests have been more thoroughly investigated in the West than has the tree itself. Numerous papers have contributed to our knowledge of the nature of the understory vegetation associated with aspen. Lynch's (1955) studies provide a useful understanding of the understory vegetation of aspen in northern Montana. The nature of the understory in Wyoming is set forth by Reed (1952) and Hoff (1957). For Colorado, papers by Costello (1944), Hoff (1957) and Langenheim (1963) give useful data for the aspen type. In Utah, Allan (1961) and Ream (1963) provide data on the understory of aspen in the Wasatch Mountains and Ellison and Houston (1958) discuss the production of herbaceous material under the canopy and in treeless openings of aspen forests of central Utah. Houston (1954) published a "condition" guide for aspen ranges in the Intermountain Region which gives some idea of the impact livestock have had on the type. In none of the fore-going papers, however, has there been a major attempt to relate the performance of individual species or groups of species to specific characteristics of the abiotic environment or to the performance of aspen itself.

Although the relationship between soils and aspen site quality have been studied in the past by several midwestern workers (Kittredge 1938, Heinselman and Zasada 1955 and Graham, Harrison and Westell 1963), such studies are not now available for western America. Furthermore, midwestern studies have been only partially successful in attempts to predict site quality for aspen from a knowledge of associated herbs.

A major objective of this study will be to determine how aspen and associated species respond to changes in the abiotic environment. Soil profile characteristics (both chemical and physical to a depth of five feet), topographic characteristics, winter snow pack, and summer soil temperature conditions will be correlated with tree and understory composition and production. The statistical relationships between environmental and vegetational variables will also be determined. Through new and improved field and laboratory procedures, it is hoped that the relationships between site quality for aspen and understory composition can be understood well enough to permit the use of understory vegetation as an accurate predictor for aspen site quality.

IV. RELATION TO PREVIOUS WORK DONE ON PROJECT

Many of the vegetational and soil sampling techniques currently used in this laboratory were developed while studying vegetational and edaphic characteristics associated with aspen "strips" in Big Cottonwood Canyon, Salt Lake County, Utah (Crowther and Harper 1965). In that study it was found that the distribution of aspen and many assocaited species was strongly influenced by parent material and by water storage capacity in the surface 5 feet of soil.

The fact that nearly all of the aspen forests in western America are grazed poses a serious problem in interpretation of ecological data from these forests. One is always faced with the possibility that a given species is absent or infrequent in a given stand because of grazing and not because the abiotic environment is unfavorable to the species. Failure to stratify stands according to degree of grazing disturbance thus results in uncontrolled variation which obscures correlations between plant response and abiotic environmental factors. Actual stocking rates on any given area are rarely known, however, making it impossible to order stands directly according to intensity of use. There has thus been a need to develop objective methods for inferring grazing use from a study of understory vegetation. During the past year an important part of our program at this laboratory has been concerned with developing methods suitable for objectively estimating the degree of prior grazing disturbance in individual stands.

By means of paired stands along fence lines grazed at differing intensities on the two sides, a total of 23 aspen forest species which increase or decrease to a statistically significant degree with grazing have been detected (Hutchins and Harper 1965). These species have been used to derive an index of inferred grazing disturbance for 75 stands (Harper and Hutchins 1965). Stands ordered on the basis of the resultant indices show strong trends across the gradient in respect to understory cover, floristic richness and quadrat frequency of indicator and non-indicator species. Furthermore stands of similar index value display significantly greater vegetational similarity than do stands of dissimilar index value. Thus by stratifying stands according to similarity of index values, we believe that we can control a major portion of the vegetational variation caused by grazers. The influence of various abiotic variables on plant response can thus be studied while the apparent influence of grazers is held somewhat constant.

During the 1965 growing season, the program outlined in this proposal has been initiated. Three workers (myself and two graduate students) have devoted full time to the project. Twenty-five stands distributed from the Kaibab Plateau in Arizona to the Wasatch Mountains in northern Utah have been studied in the full detail called for in section V. of this proposal. The necessary field data forms have been prepared, sampling procedures have been tested and invaluable experience has been gained. The past summer's work has demonstrated that the entire program is operational and has permitted us to organize the field work in such a way as to expedite collection of the necessary data.

V. BROAD DESIGN OF EXPERIMENTS

A. Analysis of Community Structure and Environmental Ecology of Aspen Forests.

1. General statement of problem

There is a need to understand the manner in which the abiotic environment influences the distribution and/or production of aspen and associated species. To obtain the required data, environment and vegetation will be studied in approximately 150 aspen stands distributed throughout the Central Rocky Mountain Region (this region is here considered to include all or part of the following states: Idaho, Wyoming, Nevada, Utah, Colorado and Arizona).

2. Procedural details

a. Stand selection. Stands satisfying the following criteria and located in the designated study area will be selected: i) tree density must appear to be normal for the particular site (very sparse and very dense stands will be avoided), ii) aspen must contribute more than 60% of the canopy cover, iii) average tree age must be in excess of 30 years (since site quality is not easily related to height growth in young sprout stands), iv) stands must be at least 1/10 acre in size and be well buffered on all sides by aspen forest and v) the stand must be uniform throughout in respect to slope, aspect, topographic position, soil and vegetational pattern.

Stands will be selected on a variety of sites supporting forest cover ranging from pure aspen to aspen forest in process of conversion to coniferous forest. An attempt will be made to include stands on the full range of site conditions which support aspen in our area. Stands will be permanently marked in the field and on topographic maps so that their exact location can be easily determined on return visits. Wherever possible, stands will be located near official governmental snow courses.

b. Site description. Each stand will be exactly one-tenth acre in size. For each stand the following data will be recorded on a prepared form: i) location (state and county, township and section, National Forest, drainage system and proximity to major land marks) ii) elevation, iii) aspect, iv) slope, v) position on, length of and shape of (concave or convex) slope, vi) size of aspen forest in which stand is located, vii) nature of and distance to surrounding vegetations, viii) evidence of fire, ix) evidence and apparent intensity of grazing, x) kind of grazers involved (will be verified from Ranger District files), and xi) method used to mark boundary of stand.

c. Tree samples. A tree is here interpreted as any woody stem having a diameter at breast height (d.b.h.) in excess of 4 inches. Every tree on each of the one-tenth acre stands will be measured and the following data recorded: i) d.b.h., ii) height (using an optical range finder), iii) age at a height of 3 feet above ground, iv) presence or absence of fire scars, and v) evidence of disease. An attempt will be made to locate stand boundaries in such a way as not to include trees of different clones. When possible, sex of clone will be noted.

d. Aspen reproduction and shrub vegetation. Aspen reproduction and characteristics of the shrub vegetation will be studied in 15 quadrats (each 1/1000 of an acre in area or 6.6 feet square) randomly distributed in each stand. Aspen sprouts will be assigned to 5 size classes: the first 3 classes will be determined strictly by height, the last 2 by d.b.h. Classes 1 through 3 will be 0-1 foot, 1-3.5 and 3.5-6 feet tall respectively. Class 4 will be more than 6 feet tall but less than 2 inches d.b.h. Class 5 will include reproduction having a d.b.h. between 2 and 4 inches. Shrubs will be placed in 3 classes as follows: 0-1 foot, 1-3.5 and over 3.5 feet respectively. Aspen sprouts and shrubs will be counted by size class in each quadrat. In addition, the percentage of the quadrat area covered by shrub crowns will be estimated.

e. Herb layer. Herbage production, vegetal cover and quadrat frequency will be recorded for each species in the herb layer. The herb layer will be sampled immediately following establishment of the stand boundaries in order to minimize the effects of trampling. Herbage production will be estimated in 10 quadrats (3.3 feet square) and cover data will be obtained at 140 points using a 5-pin, point-sampling-frame. Repetitive hits will be recorded as each pin passes through the herb layer. Forty quadrats, each 1/16,000 acre in area (1.65 feet on a side), will be distributed throughout the stand to obtain frequency data. Frequency data will be taken twice in each stand: once in early spring while the vernal vegetation is present and again in the summer. A complete list of all vascular plants present within the boundaries of each stand will be prepared.

Studies of the vernal characteristics of aspen forests will necessitate a trip to the stands in at least one spring season. This is considered to be essential since such studies have not previously been made. The writer feels that information on the vernal aspect will furnish important clues to the relative stability of aspen forests. It now appears that the vernal species disappear when aspen is replaced by conifers. The vernal species also provide an important food source for pocket gophers and are perhaps related to population explosions of those animals.

f. Soil studies. A soil profile pit will be located within each stand after vegetational studies have been completed. Pits will be excavated with hand tools to bedrock or to a depth of five feet, whichever is shallower. Pedogenic horizons will be identified and the following data recorded for each horizon: i) depth, ii) texture iii) percent of volume occupied by stones of diameter in excess of one centimeter (estimated), iv) structure, v) color, vi) pH, vii) presence of carbonates, viii) abundance of plant roots and ix) degree of mottling. Whenever possible, the nature of the parent material will be recorded. Known volume samples of undisturbed soil will be collected from each horizon by means of a bulk density sampler for laboratory analyses of bulk density, particle size distribution, chemical analyses and moisture constants.

All samples will be analyzed to determine organic matter content, total nitrogen, cation exchange capacity, and "available" phosphorus, calcium, magnesium and potassium. Moisture constants to be determined will be field capacity (1/3 atmosphere of tension) and permanent wilting percentage (15 atmospheres). These constants will be determined for all samples using that portion of the sample which will pass through a 2 mm sieve.

By use of bulk density, percent course material, horizon depth and moisture constants, we hope to be able to estimate "available" water storage capacity in the upper five feet of soil for each stand. Water actually stored in the soil profile at specific times will be determined by means of a neutron probe. Neutron probe readings will be taken in all stands at different times in order to evaluate soil moisture regimes.

Soil temperature studies will also be made to determine diurnal and seasonal variations at particular depths. Recording devices linked to remote sensing elements and driven by twenty-four hour clock mechanisms will be used to study diurnal variation. Seasonal variation will be studied in individual stands by means of thin, steel-stem thermometers. It is believed that the preliminary studies will provide an adequate background on which all stands may be meaningfully compared in respect to summer soil temperatures. During mid-summer (preferably late July or early August) of the third or fourth year of the study and following a period of limited precipitation across the entire study area, all stands will be visited and soil temperatures at a depth of one foot will be taken. Data collected in the Great Smoky Mountains (Shanks 1956) indicate that such an approach can be used to evaluate temperature differences which exist between various plant communities. In this study, such data may be useful in the evaluation of factors influencing distribution of many understory species known to be primarily southern or northern in the aspen type.

g. Most of the foregoing data will be punched on IBM cards with several cards being used per stand. Further analyses will then be handled electronically. Response of individual species to separate independent variables or to combinations of variables will be studied.

B. Experimental Studies of Successional Dynamics in Aspen Forests.

1. General statement of problem

The concept of an edaphic climax of aspen will be investigated and the relative productivity of aspen and associated conifer species on a variety of soils will be determined. By studying the growth rate of aspen and spruce-fir forests along the edge of old burns and in stands in process of conversion to conifer, it is believed that much can be learned concerning the relative response of these forest types over a broad range of soil conditions. Timber managers generally assume that site index values for aspen and associated conifers vary similarly as soil depth increases (Timber Management Division, Intermountain Forest and Range Experiment Station 1963). This hypothesis will be tested and comparative data on the growth rate of conifers and aspen will be evaluated for soil characteristics other than depth. Autecological factors associated with the dynamics of forest succession in the aspen type will also be studied by means of seedling growth of the major tree species involved. Seedlings will be grown under controlled conditions in the laboratory and a variety of conditions in the field.

2. Procedural details

a. Relative growth rate of aspen and associated conifers over a broad spectrum of soils.

i. Stand selection.
Wherever possible, stands of mature aspen and conifer will be selected in pairs along the edge of old burns. Care will be taken to select stand pairs which differ in vegetation but not in basic environment. In the event that sufficient fire-line contrasts can not be found, mature aspen stands in which type conversion to conifer is well advanced will be selected. Study areas will represent a sequence of soils ranging from raw skeletal to deep, heavy-textured profiles.

ii. Stand size.
Stands will be one-tenth acre in size.

iii. Site description.
Sites will be described as in part A, section 2, of this study.

iv. Tree layer.
The following will be recorded for each tree in the individual stands: (1) d.b.h., (2) height, (3) age at a height of 3 feet above ground, and (4) state of health.

v. Tree reproduction.
Reproduction will be studied in 15 quadrats (each 1/1,000 of an acre in area) randomly distributed in each stand. Reproduction will be classified into three size classes: sapling (d.b.h. of 1 to 4 inches), large seedling (over 1 foot tall but d.b.h. less than 1 inch) and small seedling. Age, d.b.h. and height will be recorded for saplings.

vi. Shrub density and cover.
Shrub density by species will be recorded in the same quadrats used for sampling tree reproduction. Percentage of total quadrat area shaded by shrubs will also be estimated for each quadrat. In addition, maximum height and percent cover will be recorded for individual shrub species in each quadrat.

vii. Herb layer.
The herb layer will be studied in respect to cover and quadrat frequency. Twenty-eight frames of 5 pins each will be randomly distributed in each stand to determine cover. Frequency data will be taken in 40 quadrats each 1/16,000 acre in area (1.65 feet on a side). Frequency data for herbs will be taken twice, once to get vernal aspect and again to obtain information on the summer aspect.

viii. Soil studies.
Soil data will be taken as outlined in part A, section 6.

b. Field studies of survival of seedlings of 4 conifer species in apparently stable and rapidly successional aspen stands at 3 different elevations.

i. Stand selection.
Stands used in part A of the overall study will be utilized. If possible, all stands selected will be in Utah in order to minimize the amount of travel involved in pursuance of the research. Two apparently stable aspen stands in close proximity to a seed source of conifers and 2 stands in process of rapid conversion to conifers will be selected at each of 3 elevations. Thus 4 stands will be selected at the lower altitudinal limits of aspen, 4 at medium altitudes and 4 near the upper altitudinal limits of the species.

ii. Species selection.
The 4 most common conifer species in the aspen type are white fir, alpine fir, Douglas fir and Engelmann spruce. It is known that the true firs invade aspen stands more readily than do Douglas fir or Engelmann spruce (Baker 1925). On occasion, however, one does see stands that are being invaded by the latter species. This experiment is designed to test the relative capacity of seedlings of these species to survive under a variety of conditions. Such autecological data should help explain the observed successional patterns.

iii. Seedling source.
During the spring of 1967, 3-year-old seedlings of each of the 4 conifer species selected will be obtained from the Boise, Idaho, nurseries of the U.S. Forest Service. Experience has demonstrated (Korstian and Baker 1925) that 3-year-old seedlings transplant easily and with only moderate mortality -- younger seedlings suffer high mortality rates on transplanting. A total of 1200 seedlings of each species will be obtained. All seedlings will be grown from Utah seed sources.

iv. Transplanting.

Transplanting will take place as soon in the spring of 1967 as the soil in the individual stands can be worked. The "side-hole" planting technique will be used. Seedlings will be planted in a 3 feet, 4 inches grid pattern on each area. A total of 100 seedlings of each of the 4 species selected will be placed in each of the 12 stands. Along each grid line, seedlings of the 4 species will be successively planted. In the early summers of eacl year (1967-1969), competing vegetation will be removed from a circular area (12 inch radius) around alternate seedlings of each species. Thus one-half of the seedlings of each species will be located in a microspot of reduced competition.

v. Observations to be made.

In each stand, vegetational cover and composition will be obtained. Likewise complete soil data will be taken in each stand. During the growing season of each year, soil moisture readings to a depth of 5 feet will be taken at several points in each stand at biweekly intervals by means of a neutron scattering device. In addition, precipitation data and maximum and minimum temperatures will be taken (at biweekly intervals) at each stand during the growing season.

A planting map will be made for each stand. Utilizing the planting map, each seedling will be observed on at least 3 occasions in each of the 3 growing seasons of the study. At each observation, the following data will be recorded for each seedling: 1) living or dead (if dead, possible cause will be listed), 2) height in centimeters, 3) vigor and 4) evidence of animal browsing.

c. Laboratory studies of conifer seedlings.

i. Kinds of studies to be made.

Seed of the 4 conifer species previously listed will be collected in vigorous, mixed stands of conifers (no aspen included) from 2 locations that are situated well within the normal altitudinal range of aspen. Both locations will be in the Wasatch Mountains of Utah. Seeds collected in the fall of 1966 will be sown in 1967 in pots in the greenhouse on surface soils (upper 8 inches) from the following 6 sites: 1) the 2 conifer stands from which seed was collected, 2) 2 apparently stable aspen stands in the near vicinity of the conifer stands just mentioned and 3) 2 aspen stands (not heavily grazed) in process of rapid conversion to conifers and in the same general area of the 4 preceding stands.

ii. Soil analyses.

Soil samples from each of the 6 stands will be completely homogenized and analyzed for particle size distribution, pH, organic matter, total N, leachable P, exchangeable K, Ca, Mg and cation exchange capacity.

iii. Growth studies.

A total of 25 seedlings of each of the 4 species will be grown on each of the 6 soils. Seedlings will be grown in the greenhouse in 1-quart, drained, clay pots for approximately 1 year.

At monthly intervals, the following data will be recorded for each seedling: 1) living or dead, 2) height in centimeters, and 3) vigor. At the end of the experiment, surviving seedlings will be clipped at soil level and oven-dried. Also the root system of seedlings will be washed free of soil and oven-dried. Root-to-shoot ratios will be computed for each individual, species and treatment. Tops will be analyzed for nitrogen, phosphorus, potassium and calcium. All results will be statistically analyzed. These studies should help to evaluate the influence of chemical factors apart from those of competition and soil physical conditions (poor aeration, etc.) which may be influencing successional patterns in the field.

d. Development of a "Total Site" classification system.

i. General statement of problem.

Data collected in Part A of this study will be analyzed in such a way as to classify each study area with respect to its productivity for 1) aspen and 2) understory vegetation. Site potential for aspen will be determined from height-over-age relations (Baker 1925). Herbage production will be obtained from a combination of clipping and weight estimation techniques. For herbage production, it will probably prove advisable to eliminate stands having grazing distrubance indices (see the "Previous Work" section of this proposal) in excess of a given value. High indices indicate extreme modification of the understory by grazers.

Since understory species will be used as indicators of site potential for both tree and herbage production, it will probably be necessary to prepare separate classification systems for major subdivisions of the Central Rocky Mountain Region. Preliminary observations indicate that aspen associates with such a broad range of species that southern stands have almost no understory species in common with northern stands. A similar floristic break may occur between Colorado and Nevada stands.

ii. Procedural details.

By means of electronic computers and simple and multiple regression analysis, the best combination of site variables for predicting height growth of aspen or herbage production in the understory will be identified (Schultz and Goggans 1961 and Leone 1961). With this information, one can formulate a predictive equation for either of the dependent variables utilizing only data from the abiotic environment. Attempts to utilize understory species as indicators of site potential for either tree growth or herbage production have not usually been successful (Kittredge 1938 and Discoll 1963). However, a few workers have used understory species as indicators of site potential with considerable success (Gadnon and MacArthur 1959, Hills and Pierpont 1960 and Daubenmire 1962).

Attempts to utilize understory species as indicators of site potential for either tree growth or herbage production have not usually been successful (Kittredge 1938 and Discoll 1963). However, a few workers have used understory species as indicators of site potential with considerable success (Gadnon and MacArthur 1959, Hills and Pierpont 1960 and Daubenmire 1962), but methods employed have not been quantified.

In this study, an attempt will be made to develop a simplified and completely quantitative approach to the use of understory species as indicators of site quality. Statistical reliability of indicators will be verified, a maximum number of indicators will be employed, and a straight forward technique for integrating response of many indicators will be devised. Once the indicators have been selected, any person able to identify the species can derive the index value for any given site.

All stands will initially be ordered according to site indices derived from tree height-growth data. In each classification, the linear orderings of stands will be divided into five segments of equal length. Average frequency values for each understory species will be obtained for each segment and the resultant values plotted. Species showing distinct "peaks" in a given segment will be tested for significance as "indicators" for that segment. Species "peaking" in a given segment will be weighted by an arbitrary number with each segment being assigned a different number. By multiplying percent frequency values for each species in a given stand by the "indicator value" derived from the ordination and dividing the resultant sum by the sum of the frequency values for the species, one can derive an index value for each stand. Stands can then be ordered according to the index values. The reliability of the indicator method in predicting site potential for tree growth or herbage production will be tested by simple statistical correlation.

VI. PERSONNEL

Principal Investigator

Name:	Kimball T. Harper
Date and Place of Birth:	February 15, 1931, Oakley, Idaho
Academic Degrees:	B.S. Agronomy, Brigham Young Univ. 1958 M.S. Botany, Brigham Young Univ. 1960 Ph.D. Botany, University of Wisconsin 1963
Professional Experience:	Teaching assistant, BYU, 1957-58 and 1958-59 school years. Range Conservationist, U.S. Forest Service, Summer 1957. Range Conservationist (Research), Intermountain Forest and Range Experiemnt Station, Summers of 1958 and 1959. National Science Foundation Fellow, 1959-60, University of Wisconsin. Research Assistant, Univ. of Wisconsin, 1960-63. Assistant Professor of Botany, University of Utah, 1963 to present.
Professional Societies:	Society of Sigma Xi American Society of Range Management Ecological Society of America Utah Academy of Science, Arts & Letters Wisconsin Academy of Science, Arts & Letters

Publications:

Vegetational and edaphic characteristics associated with aspen "strips" in Big Cottonwood Canyon, Utah. 1965. Proc. Utah Acad. Sci., Arts and Lett. In press, about 10 pages. (with E.G. Crowther).

Evaluation of grazing disturbance in Utah aspen forests. 1965. Bull. Ecological Soc. of America 46: 47, Abstract. (with S.K. Hutchins).

A method for determining grazing indicators in aspen communities. 1965. Proc. Utah Acad. Sci., Arts and Lett. In press, Abstract. (with S.K. Hutchins).

Structure and dynamics of the maple-basswood forests of southern Wisconsin. 1963. Diss. Abstr. 24(6): 2239

VII. FACILITIES

Two adjacent, moderate-sized laboratory rooms (approximately 1000 sq. ft. of space) have recently become available for our use in ecological research. The labs are equipped with abundant bench space, a large fume hood and the necessary utilities for routine laboratory work. Sufficient space is available in the labs to accommodate four workers.

Most of the laboratory work associated with the proposed research project will consist of analysis of various physical and chemical properties of soils. Inasmuch as the University of Utah has not operated a bonafide soils lab previously, there is a shortage of the required equipment for soil analyses. Major items of equipment currently available in the lab includes a pH meter, a microKjeldahl digestion rack, a microKjeldahl distillation apparatus, a soil dispersion mixer, two torsion balances, a set of soil sieves, a hot plate, hydrometer jars for mechanical analysis and a drying oven. Available elsewhere in the department are a spectrophotometer, a flame photometer, an ashing oven, an autoclave, a deep freeze and a well equipped shop.

The necessary equipment (altimeters, compasses, abney levels, range finders, tree increment borers, plant presses, camera, soil bulk density sampler, soil thermometers, soil color chart, soil augers, picks, shovels and vegetational sampling equipment) for the proposed field studies are currently on hand.

The Garrett Herbarium at this institution houses one of the largest collections of vascular plants in the Intermountain West (about 85,000 specimens). This collection will be helpful as a source of information on taxonomic and distributional problems which might arise in the proposed study.

Adequate greenhouse space can be made available through the Botany Department to meet the needs of this project.

VIII. PERMANENT EQUIPMENT JUSTIFICATION

1. A Nuclear-Chicago Neutron Scattering Device

Since frequent measurements of soil moisture in selected stands are needed, this equipment is considered necessary. It will provide a quick and accurate means of determining the amount of water stored in the surface five feet of soil. The time and effort required to obtain the desired soil-moisture data by gravimetric methods would be prohibitive.

2. A Desk Calculator

The plant ecology lab currently shares the use of a desk calculator with three other professors and their graduate students. The proposed research project would proceed much more rapidly if another calculator were available.

3. A Pressure Membrane Apparatus

Currently we have in this laboratory no mechanical method for approximating the permanent-wilting-point moisture percentage of soils. This equipment will help us determine the amount of soil moisture that is readily available to plants (assuming that moisture held against a pressure of 15 atmospheres is not available to most plants).

4. A Porous Plate Apparatus

This device will be used in conjunction with the pressure membrane apparatus to estimate the quantity of available water that can be stored in a given soil. This device will permit us to subject soils to known pressures in the range between 0 and 1 atmosphere.

5. A Five Kilogram Balance

We currently do not have a balance capable of weighing in one lot the samples obtained with our bulk density sampler. A balance of greater capacity would speed the processing of the soil samples.

6. A Refrigerator

There is not now a refrigerator available for our use. Various reagents, plant specimens, film etc. would be stored in the refrigerator.

7. A Four-Man Tent

Nearly all of the research on this project will be conducted on National Forest lands that are far removed from localities where lodging might be obtained. The field work will proceed more rapidly and at less expense if we can stay in the vicinity of our work.

8. A Colorimeter-Spectrophotometer

Although two colorimeter-spectrophotometers are now available in the department, they are used regularly for research and teaching. In addition they are housed in a laboratory that is located about one-fourth mile from the plant ecology laboratories. Considerable time would be saved if our laboratory also had a colorimeter for use in analyses for phosphorus and total nitrogen.

IX. CURRENT SUPPORT

During the past year a grant from the Office of Cooperative Research, University of Utah, has permitted us to initiate the research project described in this proposal. That grant provided a total of $2,238.00 for the following purposes:

Equipment	$1240.00
Supplies	423.00
Travel	450.00
Assistance	125.00
Total	$2238.00

Also during the 1965 field season, the U.S. Forest Service has paid the salary of one of our graduate students currently studying the impact of big game on aspen forest regeneration in the Central Rocky Mountain Region. The Forest Service has agreed to pay the summer salary of this student again in 1966. Wherever possible these studies will be conducted on stands that will be studied in connection with the research project here proposed.

X. PROPOSED BUDGET SHOWING PROJECT INSTITUTIONAL COST PARTICIPATION

First Year

A. Personnel	% of time devoted to this proj.	Annual base salary	Salary Acad. Yr.	Base Cal. Yr.	Budget NSF Contrib.	U.ofU. Contrib.	Total
Principal Investigator	37.2[1]	$8,200	x		$1825	$1230	$3055
Grad. Research Asst.	100	4,000		x	4000		4000
Underg. Research Asst.	10	3,000		x	300		300
Secretary	10	4,000		x	400		400
Work-Study Student[2]	100	1,600		x		160	1600
Ph.D. Candidate (a)[3]	100	2,800		x	2800		2800
Total Salaries and wages charged to this project					9325	1390	12155
B. Indirect Costs: 44.01% of wages and salaries					5350		5350
C. Employee Benefits					785	114	899
D. Consultation[4]					700		700
E. Permanent Equipment							
Nuclear-Chicago neutron scattering device and scaler					3100		3100
Desk calculator					980		980
Pressure membrane apparatus					200		200
Balance					100		100
Refrigerator					175		175
4-man tent					120		120
Colorimeter-spectrophotometer					375		375
Misc. small equipment and Supplies					500		500
F. Expendable Equipment and Supplies							
Chemicals					350		350
Glassware					200		200
Bottled gas, cylinder rental, etc.					50		50
Photographic supplies & services					40		40
Reprints					50		50
Film badge expenses (for neutron probe)					70		70
G. Travel							
Collection of field data[5]					1100		1100
One trip to national meeting					300		300
Total Budgeted Expenditures (1st year)					$23870	$1504*	$26814

*Percentage of total project cost participation by U. of Utah = 5.61%.

All items marked by a number are explained on page 22.

Second Year

A. Personnel	% of time devoted to this proj.	Annual base salary	Salary Acad. Yr.	Base Cal. Yr.	Budget NSF Contrib.	U.of U. Contrib.	Total
Principal Investigator	37.2[1]	$8,200	x		$1825	$1230	$3055
Grad. Research Asst.	50	4,000		x	2000		2000
Underg. Research Asst.	40	3,000		x	1200		1200
Secretary	10	4,000		x	400		400
Work-Study Student[2]	100	1,600		x		160	1600
Ph.D. Candidate (a)[3]	100[2]	2,800		x	2800		2800
Total Salaries and wages charged to this project					8225	1390	11055
B. Indirect Costs: 44.01% of wages and salaries					4866		4866
C. Employee Benefits					477	177	594
D. Permanent Equipment (small items)					300		300
E. Expendable Equipment and Supplies							
Chemicals					250		250
Glassware					200		200
Bottled gas, cylinder rental, etc.					50		50
Photographic supplies & services					40		40
Reprints					50		50
Film badge expenses (for neutron probe)					70		70
F. Travel							
Collection of field data[5]					1100		1100
One trip to national meeting					300		300
Total Budgeted Expenditures (2nd year)					$15928	$1507*	$18875

*Percentage of total project cost participation by U. of Utah = 7.98%

All items marked by a number are explained on page 22.

Third Year

A. Personnel	% of time devoted to this proj.	Annual base salary	Salary Acad. Yr.	Base Cal. Yr.	Budget NSF Contrib.	U.of U. Contrib.	Total
Principal Investigator	37.2	$8,200	x		$1825	$1230	$3055
Grad. Research Asst.	50	4,000		x	2000		2000
Underg. Research Asst.	40	3,000		x	1200		1200
Secretary	10	4,000		x	400		400
Work-Study Student[2]	100	1,600		x		160	1600
Ph.D. Candidate (a)[3]	100[2]	3,000		x	3000		3000
Ph.D. Candidate (b)[3]	100[2]	2,800		x	2800		2800
Total Salaries and wages charged to this project					11225	1390	14055
B. Indirect Costs: 44.01% of wages and salaries					6186		6186
C. Employee Benefits					612	117	729
D. Permanent Equipment (small items)							
E. Expendable Equipment and Supplies							
Chemicals					250		250
Glassware					100		100
Bottled gas, cylinder rental, etc.					50		50
Photographic supplies & services					40		40
Reprints					50		50
Film badge expenses (for neutron probe)					70		70
F. Travel							
Collection of field data[5]					1100		1100
One trip to National meeting					300		300
Total Budgeted Expenditures (3rd year)					$20183	$1507*	$23130

*Percentage of total project cost participation by U. of Utah = 6.52%.

All items marked by a number are explained on page 22.

Fourth Year

A. Personnel	% of time devoted to this proj.	Annual base salary	Salary Acad. Yr.	Base Cal. Yr.	Budget NSF Contrib.	U. of U. Contrib.	Total
Principal Investigator	37.2[1]	$8,200	x		$1825	$1230	$3055
Grad. Research Asst.	50	4,000		x	2000		2000
Underg. Research Asst.	40	3,000		x	1200		1200
Secretary	10	4,000		x	400		400
Work-Study Student[2]	100	1,600		x		160	1600
Ph.D. Candidate (b)[3]	100	3,000		x	3,000		3000
Total Salaries and wages charged to this project					8425	1390	11255
B. Indirect Costs: 44.01% of wages and salaries					4954		4954
C. Employee Benefits					525	121	646
D. Permanent Equipment (small items)					200		200
E. Expendable Equipment and Supplies							
Chemicals					150		150
Glassware					100		100
Bottled gas, cylinder rental, etc.					50		50
Photographic supplies & services					40		40
Reprints					50		50
Film badge expenses (for neutron probe)					70		70
F. Travel							
Collection of field data[5]					1100		1100
One trip to National Meeting					300		300
Total Budgeted Expenditures (4th year)					$15964	$1511	$18915

*Percentage of total project cost participation by U. of Utah = 7.99%.

All itmes marked by a number are explained on page 22.

Total Proposed Budget - 4 Years

	NSF Contr.	U. of U. Contr.	Total
A. Personnel (salary & wages)	$37,200	$5,560	$48,520
B. Indirect Costs (44.01% of wages & salaries)	21,356		21,356
C. Employee Benefits	2,399	469	2,868
D. Consultation	700		700
E. Permanent Equipment	6,250		6,250
F. Expendable Equipment and Supplies	2,440		2,440
G. Travel	4,400		4.400
Total Proposed Budget	$74,745	$6,029	$86,534

*Percentage of total project cost participation by U. of Utah = 6.97%.

1. Fulltime for 2 months and 15% of time devoted to project for 10 months.
2. "Total" column under this item includes funds contributed by NDEA.
3. Ph.D. candidates will pursue academic program 1/2 time during school year and spend 2 1/2 months at full time during summer.
4. Consultation will be sought in statistical analyses and in preparation of computer programs.
5. Includes mileage allowance for vehicle rental at 13 1/2¢ per mile for 4-wheel drive carryall and 7¢ per mile for 2-wheel drive pickup. About 1/3 of travel will be 4-wheel drive. This item also includes $4/day allowance for each worker for each 24 hour period that field work keeps worker from returning to Salt Lake City.

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