INTERIOR WEST GLOBAL CHANGE PROGRAM

A Regional Component of the Forest Service Global Change Research Program
Conducted by the Intermountain Research Station and Rocky Mountain Forest and Range Experiment Station

Vision Statement

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What is Global Change?

Global Change is a collection of issues that are global in scope and drive changes in the Earth system. Most notable among these are increases in the amount of radiatively active chemicals in the atmosphere. The presence of these chemicals is likely to alter the climate of the Earth. A changed climate presents major challenges to forest resource managers.

Fundamentally, global change is a resource issue because terrestrial natural resources are needed to sustain the human experience. Effects of global change on forests and related ecosystems will need to be assessed and understood. Forests and their management must play the key role in strategies to respond to the challenges of a changing climate. These strategies will be global in scope in as much as the developed world and the developing world must together evolve sustainable resource management.

Global change research requires study of interactions between forest ecosystems and the physically and chemically changing atmospheric environment. Because the climate is being altered in such fundamental ways our empirically based management practices need to be reevaluated. Management decisions will increasingly include a climate dimension as forest and related ecosystem values, both economic and social, shift in response to the changing climate.

No doubt because it affects all of us, global change has become an international environmental issue and a "Contemporary Resource Issue" in the 1990 RPA Program. Internationally, under the auspices of the United Nations, UNEP and WMO, the Intergovernmental Panel on Climate Change (IPCC) has been established. Major objectives of the IPCC activity are (1) improve scientific understanding, (2) assess potential effects, and (3) develop response strategies. Coordinated with IPCC and under the support of the International Council of Scientific Unions, the International Geosphere and Biosphere Program (IGBP) has been established as "A Study of Global Change". The IGBP is engaged in the development and conduct of large scale international experiments to aid in our understanding of the effects of global change.

The United States Global Change Research Program (USGCRP) represents the United States Government's response to these international scientific and policy issues. The Committee on Earth and Environmental Science (CEES), under the direction of the President's Science Advisor, developed the USGCRP to assure an

integrated research approach by all federal research agencies. The CEES is currently establishing a Mitigation and Adaptation Response Strategy (MARS) involving virtually all federal agencies and tasked to ensure coordinated approaches to develop policy responses to the challenges uncovered by the global change research effort.

The Forest Service Global Change Research Program (FSGCRP) is a major component of the USDA Global Change Program and, in turn, a component of the USGCRP. FSGCRP has a management structure that consists of a National Program Coordinator reporting to the Director of FFASR, WO; and four regional Program Managers.

The Interior West Global Change Program (IWGCP) is chartered as a Research, Development and Application Program to assist in conducting and coordinating research and development at the INT and RM Stations as well as with a broader regional community of researchers; reporting on the progress of these research efforts, particularly to national and international clients; and facilitating application of results to aid the development of policy and the management of natural resources in the Interior West and in similar ecosystems around the world.

The IWGCP Mission and Scope

The Interior West Global Change Program does research, development, and application:

to identify the atmospheric influences and controls;
on interior west ecosystems;
on disturbances acting within these ecosystems, and;
on renewable resource outputs from these ecosystems;
to develop economically viable and effective strategies for resource managers to adapt to and mitigate adverse effects of a changing environment.

The IWGCP mission is developed specifically to answer the following general policy questions articulated in the FSGCP plan (USDA-FS, 1990):

1. What processes in forested ecosystems are sensitive to physical and chemical change in the atmosphere? **Or in policy terms: is there a problem?**

2. How will future physical and chemical climate changes influence the structure, function, and productivity of forest and related ecosystems, and to what extent will forest ecosystems change in response to atmospheric changes? **Or in policy terms: how serious is the problem?**

3. What are the implications for forest management and how must forest management activities be altered to sustain forest productivity, health and diversity? **Or in policy terms: what can be done about the problem?**

The FSGCP determined that Regional Programs would address these questions through the conduct of research that can be grouped into nine distinct program elements. The program elements are:

I. Energy and Biogeochemical Cycles, magnitude, feedbacks and scales;

II. Terrestrial Vegetation, physiology, morphology, genetics, community structure, function, productivity and health;

III. Water, availability and quality

IV. Aquatic Ecosystems and Wetlands, structure, function and productivity;

V. Insect, Pathogens and Microbes, magnitude, frequency and effects;

VI. Fire, magnitude, frequency, and effects;

VII. Wildlife and Domestic Species, adaptability and management;

VIII. Soil, health and productivity;

IX. Economics and Policy, values, tradeoffs and management.

IWGCP has further refined these elements to include specific research questions under each element. Appendix I presents a listing of each of these questions along with INT & RM RWU's and scientists who are addressing or are planning to address research to them.

IWGCP customers include all the usual clients of Forest Service research: other researchers; Forest Service, Bureau of Land Management, Fish & Wildlife Service, National Park Service and other federal land managers; Environmental Protection Agency and other regulatory agencies, State governments, forest dependant industry; and private land managers. However, another very significant set of customers exist. The White House level CEES representing the national focal and coordinating point for global change research is a primary client. Equally important customers are the international scientific efforts organized under the IGBP. And perhaps most important are a host of yet to be defined policy clients as the ramifications of global change begin to emerge. These currently are represented by the MARS Committee under the CEES, but ultimately will be the Congress and the people of the United States, and of the world.

To provide outputs to customers in a timely manner, the IWGCP will coordinate with the FSGCRP and others in the development of:

Assessments: of the significance of projected regional climate changes and their effects on resource;

Models: capable of predicting resource responses and representing these responses within the larger scale earth system sciences community, and;

Response Strategies: management alternatives to respond to global change, including mitigation and adaptation strategies and their economic viability and their social acceptability.

Figure 1 represents a graphic illustration of the IWGCP mission. The figure identifies that the core work under this program will be conducted within the existing RWU structures of the two stations. Specific program work will be

interactive with this "research core" and will involve the timely development and packaging of assessments, models, and response strategies.

THE IWGCP APPROACH TO ACCOMPLISH IT'S MISSION

RWU Core

In order to accomplish it's mission the Program will rely primarily on the ongoing research of Intermountain Research Station and Rocky Mountain Forest and Range Experiment Station Research Work Units (RWU), and their cooperators. This reliance is based on the fact that the natural resources in the interior west are located, by in large, on public lands; that the research programs of the Forest Service in this region are already focused on the highest priority scientific and management issues associated with these lands; and that consideration of atmospheric changes on interior west ecosystems can best be done within this existing context.

The FSGCP plan identifies an inclusive listing of potential core research activities needed to address the three national policy questions. However, being an inclusive listing not all of these studies should be conducted in each ecosystem. First, there are not sufficient funds nor capable scientists to accomplish such an ambitious task. Second, many of these research activities are of primary importance in certain ecosystems but of lesser significance in other systems. Just which activities should be conducted in which priority ecosystems must be determined.

The RWU core is organized into four distinct component programs designed to improve understanding of relevant processes in order to predict responses to the combined effects of climate and management. These projects are organized into:

Landscape dynamics research includes study of atmospheric influences on both biogeochemical cyles and ecosystem structure and function especially with ecotones between alpine and subalpine forests and semi-arid woodlands, grasslands and deserts. Research also addresses how these atmospheric influences interact with disturbance and stress phenomena to change landscape patterns.

Disturbance research seeks understanding of disturbance and stress phenomona, including especially fire, insects and disease, how they are influenced by climate and air pollution and, in turn, how they influence the atmosphere.

Managed outputs research develops the capabilities to predict consequences of forest and rangeland management within a changing atmospheric environment. It also generates the knowledge to maintain commodity resource outputs and achieve such desirable future conditions as enhanced biological diversity, preservation of threatened, endangered and sensitive species, maintaining aesthetically pleasing landscapes and achieving adequate, timely and clean water runoff.

Assessment and economics research develops the technology to conduct regional and national assessments of the effects of global change on forest and rangeland resources and seeks to understand the economic and social implications of these effects.

ASSESSMENTS

Environmental Trends

IWGCP Assessments will be identified in concert with the FSGCRP. They will include national maps and projections about changes in important resource outputs. Assessments will be developed based on climate scenarios, developed nationally and in collaboration with NCAR, NOAA, EPA, BLM, USGS, ARS and the University community. Assessments will include resource maps and projections of resource outputs and how each is likely to change given the regional effects of global change. An example of the type of assessments FSGCRP will produce is provided in the Council on Environmental Quality, 1989 publication, Environmental Trends.

These trend maps will be produced in part from data collected by newly developed monitoring networks. Forest Health Monitoring, for example, will be establishing a broad monitoring framework. Existing Long Term Ecological Research (LTER) sites established by the academic community as well as Experimental Forests and other Forest Service long term monitoring locations will be woven together to help develop a comprehensive understanding of the current condition of Interior West ecosystems. Paleoecological technologies and opportunities, may also be useful to produce information about past changes and about the response of ecosystems to those changes.

RPA

Of particular significance are the Forest and Rangeland Renewable Resources Planning Act (RPA) mandated assessments. These assessments represent the long term strategic plan of the Forest Service. The FSGCRP envisions RPA as a major client. It is significant to the IWGCP that most of these assessments are produced by scientists at the Rocky Mountain Station. In particular, a special study of the effects of global change on the Forest Service was led by Dr. Linda Joyce (Joyce, et al 1980). Dr. Joyce has the responsibility to incorporate aspects of global change in the RPA process. FSGCRP plans to work closely with Dr. Joyce in determining how global change program research and assessment results will be incorporated into RPA assessments and the RPA Program.

Carbon Cycle

A particularly significant assessment is the role of the Forest Service in the global carbon cycle. The global carbon cycle determines the concentration of CO_2 in the atmosphere. There is a large exchange of carbon between terrestrial ecosystems and the atmosphere, larger for example than the exchange between oceans and the atmosphere and an order of magnitude larger than the input from human activity. Deforestation, primarily in tropical forests, figures prominently in global policy options while afforestation has been recommended as a positive action for the United States. Forest Service activities will be reviewed with consideration of the implications for the carbon cycle (Musselman and Fox 1991). FSGCRP will develop specific carbon

cycle assessments. These may also broaden to consider the implications of Forest Service management on the exchange rates of such other significant greenhouse gases as CH_4 and N_2O.

Modeling and Model Development

Modeling is a primary tool of global change researchers. Global scale general circulation models of the coupled ocean atmosphere system have been perturbed by doubling ambient CO_2 concentrations and run for sufficiently long times to establish response climates. The fact that these response climates are considerably warmer than the present climate has helped to generate the current scientific concern about global change. But these models are deficient in many regards, especially as they represent the terrestrial biosphere and its interactions with the atmosphere. Models that more appropriately represent the biosphere and that are able to predict resource responses to anticipated regional climate changes need to be developed.

Figure 2 illustrates the components of a proposed FSGCRP system model. The three major divisions, atmospheric system, natural resources system and social/economic system, each with components that are being studies by IWGCP.

The development of models is a "corporate" responsibility of the FSGCRP working in conjunction with the USDA GCRP and other groups. Which components of this "corporate" responsibility fall to the IWGCP will be determined. However, there will still be a role for the development of appropriate models by researchers within the Program. At present, we plan to construct a shell allowing for the combination of models as shown in Figure 2.

The IWGCP will develop models, it will package existing models and it will support intra- and extra-mural model development activities. Specifics will follow from the IWGCP Strategic Plan and the FSGCRP Strategic Plan for Global Change Modeling.

Response Strategies

Response options for natural resource managers to the anticipated consequences of global change will be developed by the Program. In time this may well be the most important component of the Program. The generation of response options will result from process research studies in dialog with land managers and the IWGCP. This will be an ongoing component of the Program. The development of response strategies will be done in concert with National Program planning as well as regional program planning. Response strategies are anticipated to be part of the IWGCP starting in FY93.

Although a broad array of response strategies will be developed the following represent current thinking on their scope:

Conservative Responses

Stress, reproduction failures, and disturbance will be anticipated in high-value and special-interest ecosystems. Responses will be developed which suppress or buffer the change in ecosystem structure or disturbance regime so as to maintain current values at least to the end of the current rotation. Changes in hydrologic regimes and aquatic habitats will be anticipated and control measures developed. For example, fire management strategies to protect watershed values while neither endangering ecological health nor human safety will be developed.

Adaptive Responses

Changes in ecosystems will be anticipated and evaluated with regard to the economic and aesthetic change in the expected value of the systems. Management and land-use responses that will accelerate desirable change, capitalize on beneficial change, replace or induce disturbance, grazing patterns and silvicultural regimes, or modify forest and range structure will be tested.

Mitigative Responses

Adaptive responses which counter positive atmospheric feedback loops or enhance negative atmospheric feedback loops to retard changes in global atmospheric chemistry and global temperature will be evaluated.

Economic Consequences

The economic impact of global change on the forest and associated natural resources of the world will be studied. Special emphasis will be placed on the non-commodity values of forest and related ecosystems.

Social Consequences

Social consequences of a climate changed world may be rather significant. A unique aspect of the IWGCP will be to investigate social consequences in some depth. Through partnerships with the NCAR research group on Social Impacts, the RM Coordinator for Native American programs (Joe Mitchell), the INT research unit on recreation, the RM unit of valuation, such NGO's as Aspen Global Change Institute and the Institute for Resource Management, a broad and comprehensive perspective on the consequences of global change will be developed. It is possible that such an approach may lead to development of creative and unusual policy alternatives.

THE IWGCP STRATEGIC PLAN AND THE FY91 ANNUAL PLAN

Internal Research Leadership Workshop (3/12-13/91)

It is obvious that IWGCP will rely heavily on a "Strategic Plan." IWGCP will set about the development of a strategic plan during FY '91.

The first step in the development of this plan was a workshop that brought together the research leadership of the INT & RM Stations to review the existing research program. The existing program is based on early

consideration of which ecosystems and research activities might be considered highest priority in the interior west and a preliminary determination of RWU's whose research appears most relevant to address these research activities. These RWU's and their cooperators constitute the current core program of process oriented research. The desired outcome from this workshop of internal Forest Service research leadership was development of understanding, acceptance and support of the IWGCP mission, the role of each RWU in accomplishment of this mission, and the mechanisms that will be used by the IWGCP to pursue it's mission.

FY91 Annual Plan

The FY91 Annual plan will address the priority and mechanisms for the use of IWGCP resources. In FY91 these resources include the core research program identified in Appendix II (specific RWU's, Problem Statements and funding) and the resources contained in INT-4455 and RM-4455. The 4455 units represent a budget of approximately $250,000 after overhead, salary and operating expenses.

Details of the Annual plan will be developed following the internal research leadership workshop. Some of the necessary elements of the Annual plan are listed below:

1. Develop a strategic plan for IWGCP including specific policy questions and user needs;
   - a research program designed to answer these needs;
   - a quality assurance and control program to insure the utility of program outputs;
   - key cooperators and partnerships necessary to accomplish the research program, and;
   - resources necessary to accomplish the research program.

2. Advance the national FSGCRP by funding, in cooperation with other regional programs, internal and external research efforts in it's support, including:
   - development of nationally coordinated regional climate change scenarios;
   - support to national level model development activities,and;
   - development of nationally coordinated assessments,

3. Accelerate IWGCP core research activities by funding INT & RM RWU studies that will advance IWGCP strategic plans.

4. Accelerate IWGCP activities by funding partnerships that will advance IWGCP strategic plans.

Examples of IWGCP Research

Landscape Dynamics

RWU-RM-4452-Effects of Global Change in Alpine Ecosystem

Disturbance Science

RWU-INT-4404 - Smoke chemistry

Managed Resource Outputs Research

RWU-INT-4253 - Quantative analysis

Assessment and Economic Research

RWU-RM-4852 - Renewable resource ecology and management science.

APPENDIX I

Specific research problems identified in the FSGCRP as being of significance for the interior west are listed below. These research problems are intended to be inclusive and it is recognized that the next step in the development of the IWGCP plan is to identify priority ecosystems, and for each ecosystem, identify which of these problems are most significant and how they are best addressed. Under the element is a listing of RWU's and scientists who are addressing each question.

I. Energy and Biogeochemical Cycles

1) Observe and predict how altered climate variables (i.e. temperature, wind, precipitation, and humidity), soil moisture, and UV-B radiation will affect biological changes and carbon partitioning within ecosystems, and the ecotonal areas between them, through manipulative experiments. Old growth forests will be especially important.

RM 4452 (Schoettle, Zeller, Moir, Musselman, Regan)
RM 4302 (DeBano)
RM 4151 (Ryan)
INT 4154 (Stage)
INT 4252 (Tausch
INT 4551 (Harvey)

2) Characterize the exchange of energy and trace gases (O_3, NO_x, CO_2, CH_4) and their feedbacks between the atmosphere, the cryosphere, and ecosystems (including ecotonal areas between ecosystems).

RM 4452 (Zeller, Massman, Sommerfeld, Musselman)

3) Develop Soil-Vegetation-Atmospheric-Transfer (SVAT) models to represent ecosystem characteristics in a concise yet realistic manner to models of the atmospheric planetary boundary layer ultimately for use by GCMs.

RM 4452 (Massman, Moir, Nikolov)
INT 4153 (Hoff)
INT 4154 (Stage)
INT 4401 (Rothermel, Latham)

4) Develop and verify models that simulate advective effects of local to microclimate scales particularly between landscape units.

RM 4452 (Fox, Connell, Zeller, Massman)

5) Determine, through the establishment of a few comprehensive monitoring sites, the extent of current climate change and its influences in the Rocky Mountains.

RM 4452 (Musselman)
RM 4151 (Troendle)
INT 4153 (Hoff)
INT 4154 (Stage)
INT 4252 (Tausch)

6) Determine what techniques can efficiently establish baseline forest conditions and detect changes at the landscape level, and evaluate the validity of landscape-level process models in a statistically defensible manner.

RM 4802 (Schreuder)
RM 4302 (DeBano)
INT 4151 (Stage)

7) Develop models capable of describing ecosystem stability in the face of global change.

RM 4452 (Moir)
RM 4852 (Joyce)
INT 4153 (Hoff)
INT 4154 (Stage)
INT 4403 (Brown)
INT 4551 (Harvey)

II. <u>Terrestrial Vegetation, Life Histories and Distributions, and Community Compositions.</u>

1) Predict changes in species composition and distribution resulting from global change.

RM 4452 (Musselman, Regan, Moir)
RM 4852 (Joyce)
RM 4802 (Schreuder)
INT 4153 (Hoff)
INT 4201 (Lyon)
INT 4202 (Clary)
INT 4254 (Tausch)
INT 4403 (Brown)
INT 4551 (Harvey)

2) Determine the interrelationships between species migration and biogeochemical cycling, particularly carbon, along a climatic gradient.

RM 4452 (Schoettle)
RM 4351 (Aldon)
RM 4302 (DeBano)
RM 4802 (Schreuder)
INT 4153 (Hoff)
INT 4551 (Harvey)

3) Quantify the influence of air pollution and changing climate on wilderness-like ecosystems, especially high elevation and other ecosystem remote from human influences.

RM 4452 (Fox, Musselman, Zeller)
INT 4154 (Stage)
INT 4551 (Harvey)

4) Determine and evaluate the consequences of climatic changes on critical habitat parameters necessary for threatened and endangered plant species survival.

RM 4802 (Schreuder)
RM 4852 (Flather, Joyce)
RM 4152 (Tinus)
INT 4202 (Clary)
INT 4403 (Brown)

5) Determine and evaluate the consequences of climatic changes on conservation forestry systems in the semi-arid Great Plains.

RM 4551 (Rietveld)

6) Determine the genetic potential of important tree and shrub species to cope with changing environmental parameters.

RM 4551 (Rietveld)
RM 4152 (Tinus)
INT 4153 (Hoff)
INT 4154 (Stage)
INT 4202 (Clary)
INT 4252 (Tausch)
INT 4551 (Harvey)

7) Compare measurements of the carbon balance of trees in old growth and young growth sub-alpine forest ecosystems in order to improve the ability to predict impacts of global change on tree survival and health, and net effects on the global carbon balance.

RM 4452 (Schoettle)
RM 4151 (Kaufmann, Ryan)
RM 4802 (Schreuder)
INT 4551 (Harvey)

8) Develop economically and environmentally sound management strategies (i.e. silviculture systems) for manipulating forests to provide goods and services in view of the potential for global change.

RM 4152 (Tinus)
RM 4151 (Troendle)
RM 4302 (DeBano)
INT 4101 (Steele)
INT 4153 (Hoff)
INT 4154 (Stage)
INT 4403 (Brown)
INT 4551 (Harvey)

9) Develop and apply models capable of aggregating evolving research information about ecosystem impacts of global change into Forest Service planning and resource output prediction modeling. National resource projections, in turn, need to be incorporated into similar global resource projections in the face of global change. These projections also need to reflect forest management capabilities for adaptation and mitigation of global change.

RM 4852 (Joyce)
INT 4154 (Stage)
INT 4153 (Hoff)
INT 4551 (Harvey)

10) Identify a technique that can efficiently establish baseline forest conditions and detect changes at the landscape level, and evaluate the validity of landscape level process models, in a statistically defensible manner.

RM 4802 (Schreuder) RM 4152 (Tinus)
INT 4154 (Stage)
INT 4202 (Clary)
INT 4252 (Tausch)
INT 4403 (Brown)
INT 4551 (Harvey)

III. <u>Water Quality and Quantity, Erosion, and Sedimentation.</u>

1) Develop improved models linking evapotranspiration and cumulative watershed effects to predict water yield at the stand level. Develop logical links through GIS to model water yield at the forest and landscape level.

RM 4302 (DeBano)
RM 4151 (Troendle)
RM 4452 (Massman)
INT 4403 (Brown)

2) Predict the effects of climate change on factors governing water chemistry. Evaluate these factors along with cumulative effects from multiple land users.

RM 4302 (DeBano)
RM 4452 (Musselman, Sommerfeld)
RM 4151 (Troendle)
RM 4802 (Schreuder)
INT 4302 (Clayton)

3) Predict the consequences of global change and forest management on high country contributions to future water quantity, quality, and timing in the Arkansas, Colorado, Columbia and Missouri river systems.

RM 4302 (DeBano)
RM 4851 (Brown)
RM 4151 (Troendle)
RM 4452 (Sommerfeld)

4) Couple habitat types and transitory snow through GIS with a sediment yield model to predict slope stability change under scenarios of vegetation type conversion and climatic stresses.

INT 4302 (Megahan)

5) Develop a riparian zone sensitivity model based on hydrologic response, including streamflow and groundwater characteristics, to global change. Acknowledge the major role riparian vegetation plays in ecosystem functions. Identify the management implications resulting from this sensitivity.

RM 4351 (Aldon)
INT 4202 (Clary)
INT 4302 (Megahan)

IV. <u>Aquatic Ecosystems and Wetlands.</u>

1) Relate potential hydrologic changes resulting from climate change to fisheries habitats.

RM 4452 (Musselman)
RM 4151 (Troendle)
INT 4202 (Clary)
INT 4203 (McIntyre)
INT 4302 (Megahan)

2) Determine how a changing climate might affect the habitat and vulnerability of threatened and endangered native fish.

RM 4852 (Flather)
INT 4202 (Clary)
INT 4203 (McIntyre)

V. <u>Insects, Pathogens, and Microbes.</u>

1) Assess potential changes in epidemiology and importance of forest pests (bark beetle, DF tussock moth, western spruce budworm, armillaria, blister rust, mistletoe) in a changing climate.

RM 4501 (Shaw)
RM 4551 (Rietveld)
RM 4802 (Schreuder)
RM 4152 (Tinus)
INT 4153 (Hoff)
INT 4403 (Brown)
INT 4551 (Harvey)

2) Determine the interactions between plant stress and pest success. Begin with pilot model interactions: 1) Budworm/Douglas fir - to study effects of changing nutrition; 2) Armillaria/pine - to study effects of climate stress.

RM 4501 (Shaw)
RM 4551 (Rietveld)
RM 4152 (Tinus)
INT 4153 (Hoff)
INT 4403 (Brown)
INT 4551 (Harvey)

3) Assess and model the effects of climate induced changes in pest impacts on resource values. Develop new political/social/economic paradigms relevant to these resource values changes.

INT 4154 (Stage)
INT 4551 (Harvey)

4) Determine the roles of selected non-pest microbes and invertebrate faunas in maintaining the health and viability of ecosystems, and predict the effects of climate change on these roles.

RM 4351 (Aldon)
RM 4302 (DeBano)
INT 4551 (Harvey)

VI. <u>Fire Severity and Occurrence.</u>

1) Develop models to predict the potential for large fires and to predict their spread and energy release characteristics.

RM 4802 (Schreuder)
INT 4401 (Rothermel)
INT 4403 (Brown)

2) Develop models to predict the release of important greenhouse gases as functions of fuel chemistry and physical properties.

RM 4351 (Aldon)
RM 4452 (Zeller)

3) Evaluate the consequences of alternative fire policies and changing ecological landscapes using global climate models with dynamic inputs from fire emissions and gas exchange models.

INT 4403 (Brown)

4) Modify guides for fire behavior, fire danger rating, and prescribed fire to enhance fire management decision-making in light of expected global change.

INT 4401 (Rothermel)

5) Develop an integrated model for predicting probable changes in fire's role in ecosystem dynamics in the Interior West.

RM 4302 (DeBano)
RM 4351 (Aldon)
RM 4802 (Schreuder)
RM 4452 (Moir)
INT 4403 (Brown)
INT 4551 (Harvey)

VII. Wildlife and Domestic Species.

1) Determine the sensitivity of domestic and wildlife species to changes in the quantity and quality of forage and habitat across the landscape under a changing climate.

RM 4852 (Flather, Joyce)
RM 4351 (Aldon)
INT 4201 (Lyon)
INT 4202 (Clary)

2) Develop methodologies to predict population characteristics of an assemblage of wild animals, such as birds, rodent, ungulates, and reptiles, responsive to climate change.

INT 4201 (Lyon)
3) Identify the effects of climate change on critical habitat for threatened and endangered species.

RM 4852 (Flather, Joyce)
INT 4201 (Lyon)
INT 4202 (Clary)
INT 4403 (Brown)

VII. Forest Soils.

RM 4302 (DeBano)
INT 4153 (Hoff)
INT 4551 (Harvey)
INT 4302 (Megahan)

IX. Economics and Policy Options.

RM 4851 (Peterson)
RM 4852 (Kent)
RM 4452 (Musselman)
INT 4802 (Schuster)

APPENDIX II

FY91 RWU's, funding levels and Problem Statements.

INT-4153 (Hoff) Silviculture & genetics

Silviculture and Genetics of Northern Rocky Mountain Conifers
RWU-INT-4153 ($55K)
Project leader: Raymond J. Hoff
Moscow, ID

Problem 1. How do we choose and implement silvicultural systems to meet a variety of land management objectives? (23%)
Problem 2. How do we maintain and restore healthy and productive forest stand conditions following disturbance? (15%)
Problem 3. What are the ecological and quantitative genetic characteristics of the following Rocky Mountain conifers: western white pine, western larch, Douglas-fir, ponderosa pine, lodgepole pine, spruce, and grand fir? (31%)
Problem 4. What are the genetic components of host-pest interactions associated with white pine blister rust, larach needle cast and needle blight, Armillaria root disease, and western gall rust? (31%)

INT-4154 (Stage) Quantitative analysis

Quantitative Analysis of Forest Management Practices for Planning and Control
RWU-INT-4154 ($362K)
Project Leader: Albert R. Stage
Moscow, ID

Problem 4. Potential effects of global climate change are not considered in current growth and yield models.

INT-4302 (Clayton) Soil & water management

Soil and Water Management in the Northern Rocky Mountains
RWU-INT-4302 ($75K)
Project Leader: James L. Clayton
Boise, ID

Problem 4. Basic hydrologic and geochemical processes that control chemical transport and atmospheric deposition effects on forested watersheds are inadequately understood.

NOTE: A new RWUD with 3 problems including related GCRP work is currently being developed.

INT-4401 (Rothermel) Fire behavior

Fire Behavior: Fundamentals & Systems Development
INT-4401 ($200K)
Project Leader: Richard C. Rothermel
Missoula, MT

Problem 1. Crown fire modeling and fire growth simulation. (25%)
Problem 2. Developing an integrated fire danger/fire behavior system. (25%)
Problem 3. Modeling fire and fire environment parameters. (25%)
Problem 4. Predicting winds and wind/fire interactions. (25%)

INT-4403 (Brown) Fire effects

Fire Effects: Prescribed Fire and Wildlife
RWU-INT-4403 ($53K)
Project Leader: James K. Brown
Missoula, MT

Problem 1. Determine relationships between biological responses and the prevailing preburn conditions and fire characteristics (70%)
Problem 4. Develop knowledge and technology for supporting the application of prescribed fire in wilderness and natural area ecosystems (30%)

INT-4404 (Ward) Fire chemistry

Fire Chemistry
RWU-INT-4404 ($412K)
Project Leader: Darold E. Ward
Missoula, MT

Problem 2. Trace emissions from the combustion of wildland fuels (80%)
Problem 3. Fuel, chemical characteristics affecting fire behavior and release of emissions (20%(

RM -4151 (Edminster) Multiple use management of Central & Southern RM forests

Multiresource Management of Central and Southern Rocky Mountain forests & woodlands
RM-4151 ($416K)
Project Leader: Carlton B. Edminster
Fort Collins, CO

Problem 1. Multiresource Consequences of Stand Management Activities Cannot be Accurately Predicted.

RM -4152 (Tinus) Stress physiology of Western Conifers

Stress physiology of western conifers
RWU-RM-4152 ($472K)
Project Leader: Richard W. Tinus
Flagstaff, AZ

Problem 1. What are the relationships between cold hardiness and other important physiological attributes? (50%)

Problem 2. What physiological mechanisms in conifers affect their resistance to injury from insects? (50%)

RM -4351 (Aldon) Restoration of semiarid watersheds in the SW

Restoration of Semi-Arid Watersheds in the Southwest
RM-4351 ($50K)
Project Leader: Earl F. Aldon
Albuquerque, NM

Problem 1. How do land management practices affect semi-arid grassland above and below-ground ecosystem properties, productivity, and influence runoff and erosion. (50%)
Problem 2. Methodology to assess site stability and ecological status and their interactions is needed (50%)

RM -4452 (Musselman) Effects of Global Change on Alpine & Subalpine ecosystems

Effects of Global Change on Alpine & Subalpine Ecosystems.
RM-4452 ($1292K--100% of RWU)
Project Leader: Robert C. Musselman
Ft Collins, CO

Problem 1. To identify and quantify processes that exchange trace gases and water vapor between the atmosphere and the earth's surface. (35%)
Problem 2. To understand how snow interacts with alpine and subalpine ecosystems. (20%)
Problem 3. Responses of natural ecosystems to atmospheric changes are poorly known. (35%)
Problem 4. Effects of global change on biodiversity, species migration, and future patterns of forested landscapes. (10%)

RM -4551 (Rietveld) Protection & improvement of trees in the Great Plains

Improvement of stress- and pest-resistance of Great Plains tree species.
RWU-RM-4551 ($492K)
Project Leader: Willis J. Rietveld
Lincoln, NE

Problem 1. Presently used tree provenances do not survive and grow well or tolerate disease and insect attack adequately in the stressful environments of the Great Plains. (25%)

Problem 2. Little is known about specific tree adaptations to resist environmental and biological stresses, and the extent of existing genetic diversity in such adaptations. (25%)

Problem 3. We lack fundamental knowledge of woody plant defense gene systems that help counter insect and disease damage, and the effects of environmental stresses and developmental factors on expression of plant defense gene systems. (25%)

Problem 4. We need to better understand pest biology and epidemiology, and the relationships among environmental factors, tree pests, and natural controls in order to develop effective integrated pest management systems for the unique and stressful environments of the Great Plains. (25%)

RM -4852 (Kent) Renewable resource ecology & management research

Renewable Resource Ecology and Management Science Research
RM-4852 ($204K)
Project Leader: Brian M. Kent
Fort Collins, CO

Problem 1. Quantitative Ecology.