Chapter 1
Introduction: Ecosystem Research in a Human Context

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THE RIO GRANDE: RIVER OF LIFE

The Rio Grande/Rio Bravo Basin, which drains a 355,500 square mile area in the southwestern United States and northern Mexico (Fig. 1), encompasses numerous land ownership boundaries, vegetation types, desert and woodland ecotones and edges, and urban and rural cultures, forming a complex array of interactive ecological systems. Historically known as the Southwest's "River of Life," the Rio Grande has lately become a subject of controversy over water resources and biological diversity. It earned the name in 1993 of "The Most Endangered River in North America" as proposed by the environmental organization American Rivers, Inc. Not only does the river form a geopolitical border between an industrialized country and a developing one, but human dependency on its waters, lands, and biotic resources reflects the traditions, economies, and social values of Hispanic, Anglo, and American Indian cultures. Sustainability of the Rio Grande's socioeconomic and ecological systems is a goal that has united diverse institutions, agencies, scientists, and private groups throughout the Southwest. This has resulted in numerous partnerships and initiatives designed to conserve the river and its way of life.

Nowhere is this controversy so heated as in the Middle Rio Grande Basin, an area frequently defined as the stretch between Cochiti Dam (southwest of Santa Fe) and Elephant Butte Reservoir (south of Socorro) in New Mexico (Fig. 2). Pressing middle Basin issues include water resource problems related to water quality, quantity, and rights; conservation of natural resources; restoration of ecosystems including control of exotic plant species and maintenance of biological diversity; overgrazing by livestock; urban expansion and human population growth; and impacts of anthropogenic changes on natural ecosystems. One of the biggest challenges facing researchers in the Basin, however, is developing new knowledge that integrates methodologies and data from different disciplines to solve complex problems that currently threaten sustainability of the middle Rio Grande Basin's ecosystems. To sustain the river and its people, it is necessary to understand (1) how historical and existing resource needs and uses by different human cultures have affected ecosystem and watershed processes, and (2) how ecosystem and watershed responses to natural and human-induced perturbations have influenced water resources, soil processes and stability, vegetation growth and ecotonal movement, riparian dynamics, biological diversity, and human use of lands.

THE MIDDLE RIO GRANDE BASIN RESEARCH PROGRAM

To address some of these issues, the Rocky Mountain Forest and Range Experiment Station of the USDA Forest Service initiated a research program in 1994 called "Ecology, Diversity, and Sustainability of Soil, Plant, Animal and Human Resources of the Rio Grande Basin." This program is funded by an Ecosystem Management grant from Forest Service Research and has a five-year duration (1994–1999). Its mission is to develop, synthesize, and apply new knowledge to aid in understanding processes, interactions, and sociocultural uses of upland and riparian ecological systems for sustaining diverse, productive, and healthy plant, animal, and human populations and associated natural resources in the Rio Grande Basin. The four problems defined by the program are: (1) knowledge is needed on short-term and long-term responses of upland soils, water, nutrients, mycorrhizae, and vegetation to historic perturbations caused by factors such as climate, grazing, fire, fuelwood harvesting, recreation, or farming, and how such responses influence dynamics, stability, and productivity of upland ecosystems; (2) research is

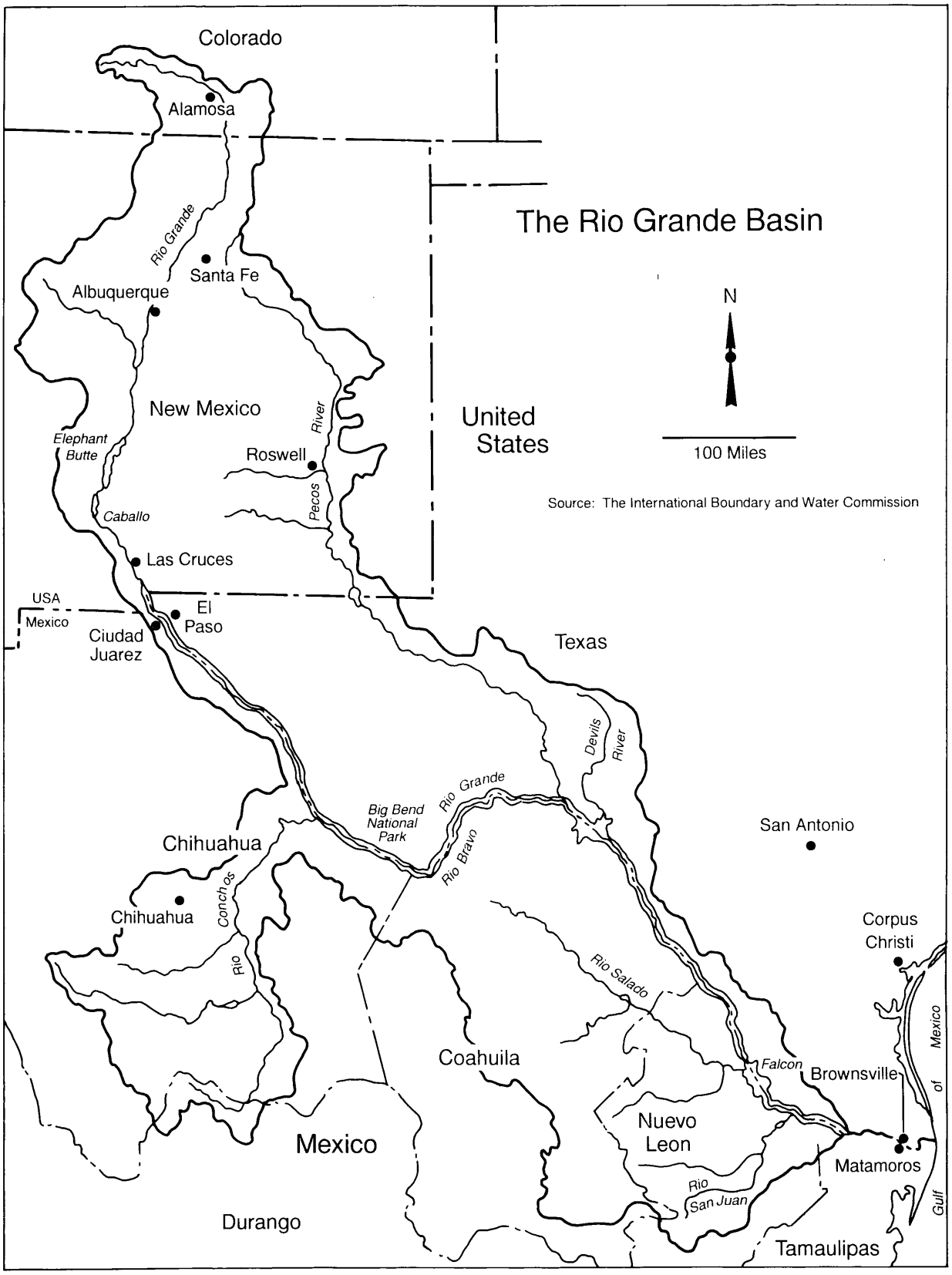

Figure 1.—The Rio Grande/Rio Bravo Drainage Basin.

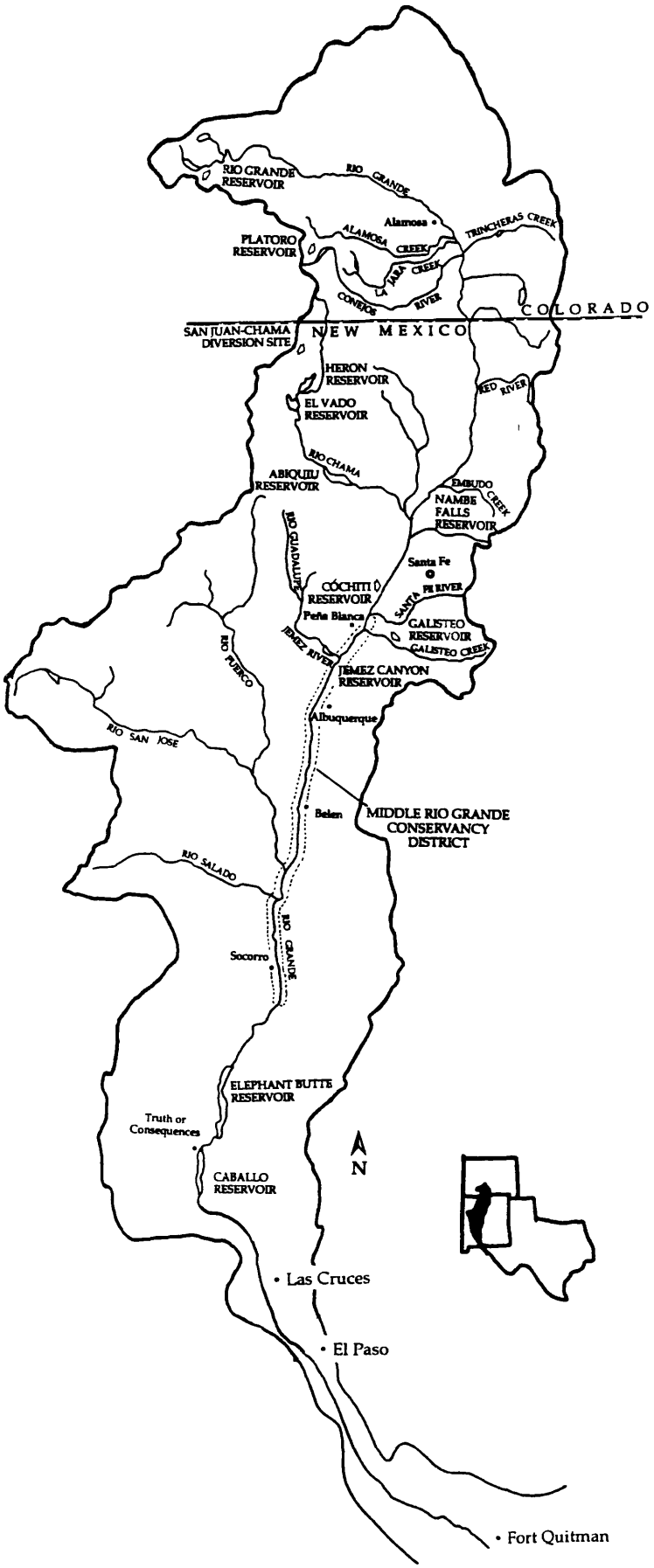

Figure 2.—The Rio Grande Basin in Colorado, New Mexico, and Northern Texas, including the Middle Rio Grande study area from Cochiti to Elephant Butte.

needed to describe spatial and temporal processes within fluvial ecosystems, past and present, that form major linkages between upland catchments (watersheds), the Rio Grande, and its floodplain bosques; (3) research is needed to determine how plant and animal species respond to barriers in dispersal, migration, and reproduction along the Rio Grande and selected tributaries; to identify those species most sensitive to corridor edges and barriers; and to develop methods for enhancing movement and survival of sensitive, threatened, and endangered species; and (4) research is needed to improve understanding of the environmental history of the Rio Grande Basin, the historic and contemporary human role in Basin ecosystems, the nature and extent of anthropogenic disturbances to the Basin, and the sustainability of cultural diversity in the Basin.

To address these four problem areas, the existing literature was reviewed and synthesized to identify high priority research and management topics in the middle Rio Grande Basin. This volume is a product of that effort, commonly called a "problem analysis" in Forest Service Research. Because Basin problems are so complex and numerous, a team of experts agreed by consensus to write separate problem analyses on a number of priority topics identified during a series of planning meetings held in Albuquerque, New Mexico, in 1994. These meetings were attended by participants and cooperators in this research program, including researchers and natural resource managers from the Forest Service, the U.S. Fish and Wildlife Service, the National Biological Service, the National Park Service, the University of New Mexico Biology Department, the University of New Mexico Natural Heritage Program, the City of Albuquerque, the U.S. Geological Survey, Wingswept Research, Inc., and the Terrestrial Ecosystems Regional Research and Analysis Laboratory. The authorship of chapters for this volume reflects the diversity of cooperators in our research program. Biographical sketches of the authors are included in the front of the volume.

Our prioritization process identified three major forces that drive ecosystem processes and dynamics in the middle Rio Grande Basin: people, water, and climate. The first three chapters in this volume explore these driving forces. Such forces cannot be adequately understood, however, without a historical context. The first chapter therefore is a brief environmental history, documenting Basin changes in ecology, biology, and human land use over time. It also identifies needed information to fill in gaps in this history. Understanding the history of a region is critical for comparing current environmental conditions to past and future conditions and for recommending solutions to natural resource problems. This is especially true in the middle Basin where native human cultures have influenced the environment for thousands of years prior to European contact, leaving behind a complex archaeological record of artifacts, architecture, and other remains; and where Hispanic people settled hundreds of years earlier than European exploration of most other parts of North America.

The second three chapters synthesize information and identify research needs pertaining to natural resource problems in major vegetation types of the middle Basin: pinyon-juniper woodlands, desert grasslands and shrublands, and the Rio Grande riparian woodland, locally known as the "bosque" (Spanish for "forest"). While higher-elevation vegetation types such as ponderosa pine and subalpine spruce-fir forests also occur in the middle Basin, problems pertaining to them were not found to be as directly linked to the integrated complex of cultural, agricultural, and biotic problems associated with the river, its tributaries, and its people. Therefore, given our limited human and financial resources, we did not address them in detail here.

The last two chapters highlight aspects of ecosystems that are often neglected in natural resource assessments and management. The southwestern United States has more threatened and endangered native fish species than most other regions of North America. In the middle Rio Grande Basin, several fish species that were historically present in the river itself are now found primarily in headwater streams. The reasons for these faunal changes are discussed and research needs identified in Chapter 8. Chapter 9 focuses on the below-ground fauna of ecosystems, a critical component contributing to ecosystem functioning, and one that is seldom managed.

In the following three sections, we review in greater detail the four problem areas and associated elements addressed by the Middle Rio Grande Research Program.

PROBLEM 1: UPLAND BASIN ECOSYSTEMS

Rio Grande Basin ecosystems have evolved under human influence for at least 12,000 years. Since 1540, the Basin has experienced increasing anthropogenic changes, including human population growth, introduction of new plant and animal species, changes in

land use, and environmental degradation. The human population in the middle Rio Grande Basin is predicted to double by the year 2020 (Crawford et al. 1993). To maintain the diversity of native grasslands, shrublands, woodlands, and forest in the overall Basin, it is necessary to identify ways to sustain human populations in the space- and resource-limited environments along the Rio Grande and its tributaries. An understanding of the history, ecology, and responses of ecosytems is dependent on the creation, synthesis, modeling, and transfer of research knowledge that describes the functional processes, structural components, and interactions of ecological systems in the context of extreme climate variability, changing human social values, and expected population growth within the Rio Grande Basin.

Fluctuations in the functional health and productivity of the Basin's arid and semiarid ecosystems are largely driven by changes in climate, water, animal, and human disturbance, including native herbivory, livestock grazing, agricultural conversion, and recreation. Extreme disturbances to grassland, shrubland, and pinyon-juniper ecosystems in the Basin contribute to soil compaction, sheet and gully erosion, reduced soil and plant productivity, desertification, invasion of exotic plants and animals, and reduced biological diversity. These problems are exacerbated by severe and unpredictable climatic fluctuations that affect water flow dynamics, nutrient availability, and energy availability along gradients of slope and vegetation. To understand how human use of the Basin's upland environments affects overall ecosystem functioning and structure, knowledge is needed concerning ecosystem responses to historic and current perturbations caused by climate, grazing, and fire, and how such responses influence dynamics, stability, and productivity of upland ecosystems.

Pinyon-juniper ecosystems occur on approximately 23 million acres in New Mexico. On National Forests alone, close to 50 percent of pinyon-juniper watersheds (about 3.5 million acres) contain degraded soils and vegetation (Henson 1993). Indeed, the Forest Service's Southwestern Region established a Pinyon-Juniper Initiative in the early 1990's for the purpose of restoring pinyon-juniper watersheds to a healthy state (Henson 1993). Degraded conditions associated with historical and current overgrazing in the middle Rio Grande Basin are especially visible at the interface between pinyon-juniper woodlands and desert grasslands and shrublands. Pinyons and junipers in these transitional zones or ecotones may have been historically subjected to higher fire frequencies than interior pinyon-juniper woodlands, owing to frequent lightning-caused fires in grasslands (Tom Swetnam, personal communication). Without the restoration benefits of fire, soils and cover of grasslands and adjacent ecotones can deteriorate, especially under heavy livestock use. In grasslands with juniper as an overstory species, grazing results in a competitive advantage to juniper and a reduction in grass production (McPherson and Wright 1990). Removal of grass cover and degraded soil conditions, including soil compaction and accelerated erosion, can lead to reduced long-term soil productivity and impaired water quality. These upland ecosystem processes and dynamics are addressed in more detail in Chapters 4, 5, 6, and 9.

PROBLEMS 2 AND 3: WATER, WATERSHEDS, AND RIPARIAN ZONES

Climate change, and corresponding patterns of rainfall and drought, can cause further havoc in ecosystem processes controlling water flow and vegetation distributions. The amount and quality of runoff entering the Rio Grande and its tributaries from pinyon-juniper and desert grassland watersheds influence the dynamic connections among river water, the riparian zone, and biotic diversity. The reproductive and nutritional state of native vegetation in the Rio Grande's riparian zone reflects the magnitude and chemistry of seasonal flooding, which is a function of watershed runoff. Unsatisfactory watershed conditions contribute to increased overland flows, eroded stream banks, and non-point source pollution.

From an ecosystem perspective, managing the quantity and quality of nutrients and sediments delivered from upland watersheds to the Rio Grande and its tributaries should be a major goal of Basin management. The second and third problems defined under our research program deal more specifically with water, riparian habitats, and associated wildlife and fish. The literature related to these problems is reviewed in Chapters 4, 7, and 8.

Historic and contemporary land use practices, especially grazing, mining, and fuelwood harvesting, coupled with severe drought periods, have led to high rates of surface runoff and sediment yield from upland grassland and pinyon-juniper watersheds into Basin tributaries such as the Rio Puerco. This has jeopardized the health and regenerative capacity of riparian plant and animal populations and com-

munities. Sediment pollution detrimentally affects native fish populations. Current livestock grazing in the uplands, if managed poorly, can reduce herbaceous cover and compact soils, leading to erosional and runoff problems that ultimately impact riparian zones. Overgrazing within the riparian zone can also reduce the regeneration capacity of native cottonwoods and willows, potentially deteriorating habitats used by wildlife and people. Loss of native riparian vegetation owing to overgrazing, agricultural and urban conversion, and replacement by exotic woody plants may ultimately disrupt the migration and breeding dynamics of neotropical migratory birds along the Rio Grande flyway and may explain the population decline of the endangered southwestern willow flycatcher (*Empidonax trailii extimus*).

The Rio Grande has long provided many resources, including drinking water, travel pathways, fuelwood, and fish and game for indigenous and recent human populations. Today, a continuous corridor of transportation and communication links contemporary urban environments along the main stem of the Rio Grande. Europeans built water diversion structures, cleared riparian vegetation, planted non-native species, and constructed dwellings and villages in the Rio Grande bosques. Dams, groundwater pumping, agricultural developments, and urban centers along the main river valleys have impacted the nature, extent, distribution, and regenerative health of floodplain bosques. Exotic plant species have invaded most river systems in the Basin, forming potential barriers to dispersal, migration, and reproduction of native plant and animal species. Water pollutants from urban centers, non-point source pollution from overgrazed uplands, and introduction of exotic salmonids and bullfrogs have eliminated native fisheries along the Rio Grande, endangering some fish species by isolating them in headwater streams or in remnant pockets of the river itself. Although the middle Rio Grande bosque appears continuous, in actuality it is "fragmented" by centers of human habitation, the presence of exotic plant and animal species, dams and diversion structures, and a system of protected parks and wildlife refuges interspersed by nonprotected stretches used by livestock. Chapter 7 explores the dynamics of the Rio Grande bosque, emphasizing the relationships among three taxonomic groups and trophic levels, while Chapter 8 focuses more specifically on the fish fauna in the Basin.

In the final section, we explore in greater depth the human dimensions part of our program because it is the integration of human needs and values that makes our program especially valuable and unique in the arena of environmental research.

PROBLEM 4: HUMAN DIMENSIONS

Environmental Issues as Human Values

In the United States today and throughout the world, there is increasing disagreement over policies of land management and natural resource use. Many of these disagreements concern basic political and economic goals. Others, more subtle and difficult to understand, are expressed as differences in cultural values and perceptions, or as traditional ways of using land. Disputes and conflicts that are expressed in cultural terms have become common over the past three decades. This is a worldwide phenomenon. Such disputes over culture and environment manifest themselves in a continuous spectrum. At one end of this spectrum are the comparatively benign land disputes fought mainly in the courtrooms and legislatures of the United States, Australia, and Canada. At the opposite extreme there are the terrible conflicts that we see in Rwanda, Liberia, and Bosnia. Because these disputes are global in their occurrence and continuous in their expression, they are best comprehended in a comparative framework. In the United States, agencies that manage public lands experience one part of this global pattern. This is part of the reason why comparative cultural research is of importance to the USDA Forest Service and other land-managing agencies. The human dimensions component of the Rio Grande Basin research program will be a major part of that comparative research.

Conflicting cultural perceptions and goals in land use underscore an important point: environmental problems are essentially human problems, and solutions to them require more than the traditional biophysical approaches. Too often, those who work in natural resource management have not foreseen that their work has social and cultural consequences. Especially in places where cultural diversity is high, and where land and resource use differ by cultural group, how people use the land can easily become a part of cultural identity. It can also be part of a strategy to resist assimilation. The issues that arise from threats to traditional land use are more than merely economic. Subsistence practices and other uses of land may be no easier to abandon than any other aspect of cultural identity. These issues are particu-

larly salient in the southwestern United States, including the Rio Grande Basin.

Amidst today's cacophony of land-management appeals, litigation, and contentious political discourse, one point should be clear: sustainability is a human value judgment. There are no absolute standards to which ecosystems should be maintained or restored. People assign meaning to landscapes (Greider and Garkovich 1994), and those meanings may be quite different from how a biologist or a forester sees a landscape. What we perceive as a desirable landscape condition reflects social values as much as it reflects ecosystem characteristics. Confounding matters, such values change over time. To illustrate, consider some historical changes in how our ancestors and ourselves have viewed landscapes.

In the world of the ancient Mediterranean, peasant agriculture was the basis of society and the source of most wealth. The most valued landscape was therefore an agricultural one: small peasant farmers using the land intensively to produce wealth for the elites, taxes for the state, soldiers for the army, and food for all. Writers of the period always commented favorably on such landscapes. Conversely, a landscape not filled with productive peasants, being allowed to revert to natural conditions, was considered to indicate a society in decline (Alcock 1993). The economic conditions that favored such a landscape ideal persisted until the Industrial Revolution. They are essentially the economic conditions and landscape values that formed the Jeffersonian theory of American democracy.

Implicit in such ideals is the assumption that lands that have not been culturally transformed are without value. Such lands may even be seen as vaguely threatening. At one extreme this produced the medieval European view that old-growth forests were places to be feared. They were dark and forbidding, and the home of witches, wolves, and robbers. Forests were where culture stopped and nature began. To enter such a place was to risk one's life. The medieval folklore reflecting such fears is still repeated today in tales told to children.

Consider how these views have changed as industrialism has transformed our economic base. The people of medieval Europe would have been astonished by the notion that old-growth forests are to be valued, protected, and actually entered for enjoyment. Thomas Jefferson could hardly have foreseen the wilderness philosophy that would emerge from the writings of Henry David Thoreau. Since the founding of this country, the view that many people have of valuable landscapes has changed profoundly. It will do so again in times to come.

What we perceive to be an ecosystem worth maintaining or restoring has much to do with what we value in landscapes. Neither ancient Romans nor medieval Europeans, not to mention Thomas Jefferson, would ever have thought to preserve land as wilderness. Sustainability is a flexible and changing judgment of human values, and managers must approach it as such.

Human Dimensions Research in the Rio Grande Basin

Including the human dimension in ecosystem research and management greatly increases the complexity of our work. Yet to leave people out is to guarantee political discord and continuing expenditure of public funds on land-management appeals and litigation. Recognizing that environmental issues are substantially human issues, many scientists and administrators have concluded that ecological problems require human solutions as much as they require strictly biophysical ones (e.g., Allen and Hoekstra, in press). The human dimensions component of the Rio Grande Basin research program reflects this growing realization. A few years ago, such a program would have been likely to include little or no human dimensions research. More recently, a brief discussion of human dimensions might have been included as an afterthought. The fact that a strong component of human dimensions research was planned into this program at the outset is an indication of how research and administration are changing in land-management agencies.

Several principles have guided the development of the human dimensions component of the Rio Grande Basin research program. The first is that there are in the world today few "natural" ecosystems, or perhaps even none, in the sense of existing without human influence. All ecosystems are anthropogenic to one degree or another. Rio Grande Basin ecosystems have evolved under human influence for at least 12,000 years, and this has particularly been so for the last 450 years. The Rio Grande Basin cannot be understood without considering the role of humans in ecosystems and human responses to environmental problems.

Recognizing that past human populations have modified ecosystems, sometimes to significant de-

grees (e.g., Lewis 1973), does not, of course, legitimize callous environmental destruction. What it should do is to change the terms of debate over historical and contemporary changes to ecosystems. Calling for the "restoration" of ecosystems to "pristine" conditions (as some environmental advocates do) exacerbates the political conflict in the United States over environmental laws. It may also be historically misguided.

A second principle concerns scale and complexity. Environmental problems occur at all levels, from local to global. Systems for managing environmental issues match this range. They can be found at every level, from local, ad hoc associations to international agencies. To consider issues of culture and environment in the Middle Rio Grande Basin requires a view that sees the Basin in context. This context involves such matters as immigration; Albuquerque's success at attracting business; economic conditions at the state, national, and international levels; the state and federal budgets; the price and availability of fossil fuels; climate; and other factors. To develop a comprehensive understanding of cultural diversity in New Mexico in its relationship to environmental factors requires research into all of these topics, as well as into the position of the Rio Grande Basin in the global economy and in the global environment.

A third principle is the importance of knowing where we are in history (Tainter 1995). Historical trends develop over periods of generations or even centuries. Because these trends cannot be comprehended in a single lifetime, it is difficult to know from personal experience where we are in the long-term cycle of human-environment interactions. The production and prices of natural resources, for example, often depend on a capital investment cycle with a lag time of up to several decades. So does employment in resource production (Watt 1992). Do current low levels of employment in the timber products industry reflect the effects of environmental laws, technological change, global economic forces, or the capital investment cycle? Unless the timber products capital investment cycle is considered, the question cannot be answered. It is important to know where we are in history.

Historical research sometimes produces surprising results. As pointed out by Dan Scurlock in this volume, the Anglo-American trader Josiah Gregg suggested in 1844 that the grasslands of the Southwest would eventually be replaced by trees and shrubs due to suppression of range fires (Gregg 1844). To encounter such a statement in the historical literature is both illuminating and disturbing. One has to wonder why it took us 150 years to rediscover that lesson.

A final principle involves the role of social and political organization in both creating and resolving environmental problems. Frank Wozniak (this volume) has described how irrigation agriculture in the Middle Rio Grande Basin had declined by the early 20th century due to a variety of environmental problems. In the 1920s the Middle Rio Grande Conservancy District (MRGCD) was organized to drain waterlogged soils, reclaim unused lands, and provide water for irrigation. This involved a reorganization of irrigation systems, a renovation of facilities, and the development of a new agency to manage irrigation. The new system brought with it an infusion of outside influences and a tremendous escalation in the costs of irrigation. Much of the latter impact was absorbed by the Federal government, which massively subsidized the cost of irrigation in the Rio Grande Valley. Many of the old problems of flooding, sedimentation, waterlogging, alkali poisoning, and unreliable water supply were resolved or at least held in check, but they were replaced by problems of financing the new system.

The formation of the MRGCD illustrates the role of political organization in human-environment interactions. Today the Middle Rio Grande Basin is embedded within larger political and financial systems at the national and international levels. While this allows the people of the Basin to tap higher political levels for financial support, it also means that the stability of the Basin depends on the stability of the larger system. There are historical examples that should be considered in appraising this stability. In the first millennium A.D., the regimes that ruled the Mesopotamian alluvium greatly intensified irrigation and agricultural production. Irrigation systems were developed that were beyond local abilities to manage and repair. State control and financing were required. In the late ninth and tenth centuries A.D., however, the political hierarchy became unstable, and the irrigation system declined catastrophically. Fields became salinized and production plummeted. By the eleventh to twelfth centuries A.D. the total occupied area had dropped by about 94 percent. Populations declined to the lowest levels in five millennia. Tax revenues plummeted by 90 percent within a few decades. People rebelled and the countryside became ungovernable. For centuries afterward, this catastrophe eliminated the basis for urban life in 10,000

square kilometers of Mesopotamia (Adams 1981; Waines 1977).

The point of this illustration is not to suggest any direct parallel between ancient Mesopotamia and the Middle Rio Grande Basin. The analogy is more subtle. It lies in the dependency of local systems of production and management on higher levels in a complex system, and the risks that this dependency entails. The very highest levels in political systems have always been prone to failure. This is because problem-solving in such systems displays a characteristic historical pattern of increasing complexity, the creation of costly institutions, and ultimately diminishing returns to problem-solving. This simple pattern has profound implications. In a system of problem-solving that develops in this way, eventually the point is reached where it is no longer feasible or beneficial to try to solve problems. In time such systems are either terminated or they collapse (Tainter 1988, 1995), as happened in ancient Mesopotamia. Systems for managing environmental and cultural issues are no exception to this. In these days when we know that the cost of government is not sustainable, it is probably unwise to depend on the political hierarchy to solve local problems with financial subsidies. It is worth noting that the MRGCD has received no federal funds for the past several years.

Working within these principles, the human dimensions portion of the Rio Grande Basin research program contains five elements.

The first research element is to improve understanding of the human role in Rio Grande Basin ecosystems, including historic and contemporary human ecology, and human responses to climatic and other environmental changes. When land managers consider the human role in ecosystems, it is usually as a dichotomy: human dimensions or natural ecosystems. This dichotomy is misleading and channels discussion in unproductive directions. Human populations are *of course* parts of ecosystems. The relationship of culture to environment is reflexive: Each influences and conditions the other. North American ecosystems have developed under varying degrees of human influence. At the same time, both prehistoric and historic North American cultures have been influenced by environmental conditions. To debate whether to include human populations in the analysis of ecosystems is like debating whether ecosystems include both flora and fauna.

What we do not yet know is the extent to which the historic conditions of Rio Grande Basin ecosystems were conditioned by prehistoric human activities. In some parts of North America, Indian populations deliberately manipulated ecosystems to select for early seral stages (e.g., Lewis 1973). Research is needed to determine if this was also the case in New Mexico. Our conception of such matters as the range of historic ecosystem variation will depend substantially on the outcome of such research.

The second research element is to establish historical information on changes in the Rio Grande Basin and to improve understanding of the evolution of Basin ecosystems since 1540. Dan Scurlock's contribution to this volume falls within this research element. It is a prologue to a much longer work in progress that he is preparing for both the Rio Grande Basin research program and the Cultural Heritage Research Work Unit of Rocky Mountain Station. This report will be a full synthesis of the documentary evidence for environmental change in the Middle Rio Grande Basin since 1540. Such knowledge should be the basis of any attempt to understand current environmental conditions.

The third research element is to develop an integrated understanding of the relationships among environmental, cultural, political, and economic factors and processes within the Rio Grande Basin. The Rio Grande Basin is noted for its cultural mosaic. The cultural identity of some Basin groups is formed in part through their relationship to the land, while maintaining cultural identity depends on an adequate economic return from use of the land. An integrated understanding of the relationships among environmental, cultural, and economic factors and processes within the Basin is needed to sustain both human populations and natural resources. Where perceptions and uses of land vary by culture, this may lead to conflict over land and resources. Ecosystem management, which is a concept of European analytical thought, is increasingly constrained by values and perceptions arising from other cultural contexts. To predict human responses to changes in land management and to manage conflicts resulting from change, we need to understand better the perceptions and values of nature, land use, and land management held by different cultural groups in the Rio Grande Basin. We also need to improve understanding of the relationship of cultural sustainability to changes in climate, energy, population, land use, the national and global economies, and the environment. We need to understand alternative cultural responses to changes in these factors. The contribution by Frank

Wozniak in this volume explores some of these relationships.

The fourth research element concerns developing or refining methods to assess the impacts of alternative resource-allocation decisions within the Basin. It also concerns how adverse social and cultural impacts of allocation decisions can be mitigated. Existing models of conflict resolution, mediation, and prevention should not simply be applied untested to the Rio Grande Basin. Their suitability to Basin conflicts needs to be determined. If necessary, new models should be developed that are specific to the characteristics and problems of this area. Such new methods may be needed to help the people of the Basin visualize and understand better the impacts of alternative resource allocation decisions

The final research element is closely related to the fourth. It is to improve ways to obtain consensus on, and commitment to, the desired future conditions of the Basin from the area's many interest groups, agencies, and institutions. The Rio Grande Basin is one of the most culturally diverse parts of North America. That diversity must be recognized to achieve a consensus on future conditions of the Basin.

Cultural Diversity in Context

As noted above, we are experiencing a dramatic increase in the formation and expression of cultural identity. This is nearly global in its occurrence, and in its present form it is a phenomenon largely of the last 30 years. It is something nearly unique in human history. This global intensification of cultural identity and cultural conflict manifests itself in the Rio Grande Basin, as it does elsewhere.

We understand poorly the basis of cultural identity or the reasons for cultural conflict. Journalists, among others, seem to assume that cultural differences lead automatically to violence. Commonly in the media one encounters attempts to explain violence as the sad but inevitable result of "ancient tribal feuds." Violence is thus assumed to be something intrinsic to cultural differences. Such is the picture of cultural diversity that is presented to the public. It is a great oversimplification and a terrible misunderstanding of the basis of cultural conflict.

Two recent conferences, one of which was organized by the Cultural Heritage Research Work Unit of Rocky Mountain Station,[1] have shown that these popular "explanations" of cultural conflict are fundamentally incorrect. The results of these conferences suggest that many so-called "cultural" conflicts may not really have cultural origins or cultural solutions. In the discussions at these conferences it was consistently clear that contemporary incidents of violence, each supposedly a clash of cultural identities, are closely linked to political struggles in the relations of local groups to central governments or are actually about control of central governments. Cultural differentiation in today's conflicts is flexible and shifting, and it responds to both external stimuli and deliberate manipulation.

To an outsider or casual observer it is easy to suppose that conflicts between different cultural groups are conflicts *about* culture. In fact, in many of the conflicts occurring around the world today, people struggle not for their culture but for more fundamental economic and political issues that happen to be expressed in cultural terms. To phrase an economic or political claim (such as a claim to have a role in managing public lands) in cultural terms raises the moral authority of the claim and taps profound emotions. It is an effective strategy of public discourse.

This point has important implications for addressing cultural disputes in land management. If such disputes have an economic or political basis, but are expressed in cultural terms, then to address only the cultural issues is not to resolve the problem. The underlying economic or political conflict may remain. This is not to deny that people often have strong feelings for traditional uses of land. Such uses are often a central part of cultural identity and may be no easier to abandon than religion, language, or community. The point is that if attempts to mediate disputes address only expressed cultural issues, the attempts will fail. The fundamental economic and political disputes must be resolved as well. This is as much the case in the Rio Grande Basin as it is in Bosnia, Rwanda, or Tajikistan. The label "cultural conflict" may conceal much more than it reveals.

CONCLUDING REMARKS

It is clear that resolution of environmental problems must come from integrated research by natural

[1] *The first conference was* The State Under Siege: Political Disintegration in the Post-Cost War Era, *organized by R. Brian Ferguson,* [1] *(continued) New York Academy of Sciences, April 22–24, 1994. The second was* Environmental Dimensions of Cultural Conflict, *organized by Joseph A. Tainter and R. Brian Ferguson, Xerox Document University Training Center, Leesburg, Virginia, June 18–22, 1995.*

and social scientists working together. Leaving out either component of this mix will result in failure. The level of interdisciplinary research in the Rio Grande Basin research program, exemplified in this volume, is unique in our experience. It points the way to the future. If we find solutions to the problems of the Rio Grande Basin, it will be because we find new ways of organizing research so that it is truly interdisciplinary, integrated, and synthetic. We need multidimensional research and management to understand and solve multidimensional problems.

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REFERENCES

Adams, Robert McC. 1981. Heartland of cities. Chicago: Aldine.

Alcock, Susan. 1993. Graecia Capta: the landscapes of Roman Greece. Cambridge: Cambridge University Press.

Allen, T. F. H.; Hoekstra, Thomas W. Sustainability: A matter of human values in a material setting. In: Aguirre-Bravo, Celedonio et al., tech. compilers/eds. [In press]. Partnerships for sustainable ecosystem management: 5th Mexico/U.S. biennial symposium. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station.

Crawford, Clifford S.; Cully, Anne C.; Leutheuser, Rob; Sifuentes, Mark S.; White, Larry H.; Wilber, James P. 1993. Middle Rio Grande ecosystem: bosque biological management plan. U.S. Fish and Wildlife Service, Albuquerque, NM. 291 p.

Gregg, Josiah. 1844. Commerce of the prairies, or, the journal of a Santa Fe trader, during eight expeditions across the great western prairies, and a residence of nearly nine years in Northern Mexico. New York: H. G. Langley.

Greider, Thomas; Garkovich, Lorraine. 1994. Landscapes: the social construction of nature and the environment. Rural Sociology. 59: 1–24.

Henson, Larry. 1993. The Forest Service's piñon-juniper initiative for the Southwest. In: Aldon, Earl F.; Shaw, Douglas W., tech. coordinators, Managing Piñon-juniper Ecosystems for Sustainability and Social Needs, p. 23. General Technical Report RM–236. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station.

Lagasse, P.F. 1981. Geomorphic response of the Rio Grande to dam construction. New Mexico Geological Society, Special Publication No. 10, 1982:27–46.

Lewis, Henry T. 1973. Patterns of Indian burning in California: ecology and ethnohistory. Ramona, CA: Ballena Press. Anthropological Papers 1.

McPherson, Guy R.; Wright, Henry A. 1990. Effects of cattle grazing and Juniperus pinchotii canopy cover on herb cover and production in western Texas. American Midland Naturalist. 123:144–151.

Tainter, Joseph A. 1988. The collapse of complex societies. Cambridge: Cambridge University Press.

Tainter, Joseph A. 1995. Sustainability of complex societies. Futures. 27: 397–408.

Waines, David. 1977. The third century internal crisis of the Abbasids. Journal of the Economic and Social History of the Orient. 20: 282–306.

Watt, Kenneth E. F. 1992. Taming the future: a revolutionary breakthrough in scientific forecasting. Davis, CA: Contextured Webb Press.