INTERNATIONAL ARID LANDS CONSORTIUM'S CONTRIBUTIONS TO BETTER MANAGEMENT OF WATER RESOURCES IN ARIZONA AND THE SOUTHWESTERN UNITED STATES

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The International Arid Lands Consortium (IALC) was established in 1990 to promote research, education, and training activities related to the development, management, and reclamation of arid and semiarid lands in the United States, the Middle East, and elsewhere in the world. The IALC supports ecological sustainability and environmentally sound use of these lands by funding research, development, and demonstration projects related to these themes. Results from these scientific and technical efforts enhance management of arid and semiarid ecosystems for sustainable use within the framework of maintaining the integrity of the ecological processes involved. Among the areas receiving IALC attention are the development and conservation of soil and water resources, land use and reclamation, processes enhancing the management of ecological systems, and inventorying and measurement techniques and monitoring. Some of the contributions of the IALC to better stewardship of soil and water resources in Arizona and more generally the southwestern United States are summarized in this paper. A more comprehensive report on the accomplishments and contributions of the IALC to arid and semiarid land stewardship in its initial 10 years of existence can be found in Ffolliott et al. (2001).

GROUND WATER QUALITY AND NITROGEN FERTILIZERS

There is increasing concern in the southwestern United States about the possible contamination of ground water resources from nitrogen (nitrate-nitrogen) fertilizers applied to agricultural lands. The often excessive amounts of nitrogen fertilizer that agriculturists apply to shallow-rooted crops have resulted in the greatest contamination. Therefore, the IALC supported a project to demonstrate the use of a known chloride-tracer technology to improve nitrogen fertilization efficiency (Al-Jamal et al. 1998). Samples were taken at each of the participating farms in southern New Mexico to obtain baseline data on nitrogen-to-chloride ratios and efficiencies of nitrogen fertilizer applications. Samples obtained after adding a chloride tracer to the water were analyzed and compared to the baseline data. Using this knowledge, producers were able to make adjustments in the scheduling of nitrogen applications, which has resulted in improved ground water quality beneath their agricultural fields.

MITIGATING SOIL SEALING

Sealing of soil surfaces is a major concern in arid and semiarid environments. Sealing reduces infiltration of water and inhibits the emergence and survival of planted seedlings. One way to mitigate this sealing is to maintain a wet soil surface by frequent irrigation, but this approach is expensive and wasteful. Another way to improve soil surface structure and aggregate stability is by adding soil conditioners such as polyacrylamides (PAMs) to the soil surface. An IALC-sponsored investigation in Texas revealed that PAMs reduce the strength of soil-sealing crust, improve infiltration, and decrease the wind erodibility of soils with high sand and low silt contents (Gardiner and Carr 1998; Gardiner et al. 1998, 1999). Repeated applications of PAMs improve the persistence of these effects, although the emergence and survival of shallow-seeded plants does not appear to be consistently improved by PAMs or combinations of PAMs and gypsum. The interactions of polyacrylamides with soil characteristics, infiltration

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rates, seedling emergence, and other factors need further investigation.

USING WASTEWATER TO GROW TREES FOR PROFIT

The improper treatment and disposal of human waste affects many communities in arid and semi-arid lands by causing environmental degradation and declining public health. An IALC demonstration project served to increase awareness about environmentally sound and economically feasible wastewater treatment and disposal. Specialists in water and soil management, small-business development, and community planning from the southwestern United States and northwestern Mexico have collaborated in applying treated wastewater to landscapes unsuited for agriculture production to grow short-rotation pulpwood trees for sale in local markets. This low-cost approach safely recycles sludge and wastewater from small- to medium-sized communities along the Rio Grande on both sides of the border. This project serves as a useful model for combining wastewater treatment and disposal with economic development of other local communities.

WATER USE BY EMORY OAK

Other than precipitation, water used for transpiration is the largest component in the water budget of Emory oak stands (Ffolliott 2004). To learn more about how land-use activities affect transpiration by Emory oak—a widely distributed drought-deciduous species in the southwestern United States—the IALC supported studies to increase people's understanding of the changes in the relative proportions of water consumed by harvesting the trees for wood products and their subsequent regeneration. Transpiration rates were estimated by the heat-pulse method (Swanson 1994) in these investigations. One of the more important findings was that stump-sprouts growing from rootstocks of harvested oak trees can use up to 80 percent of the annual precipitation in the transpiration process in comparison to about 45 percent of the annual precipitation used by mature trees 60 years and older in unharvested stands (Ffolliott et al. 2003). Even though the transpiration rate of a single stump-sprout is significantly less than that of a mature tree, the greater transpiration rates in harvested stands is attributed to the large number of actively growing stump-sprouts. There is thus less water available to recharge ground water aquifers, produce streamflow, and help other plants to grow when stump-sprouts dominate a site following the harvesting of Emory oak trees. This research provides a basis for managing post-harvest oak stands to optimize water conservation and firewood production, and through the results of companion studies, to benefit other resources in these fragile woodlands (Shipek et al. 2004).

CLIMATE CHANGE, ALLOMETRY, TREE HYDRAULICS

Managers of forests and woodlands are increasingly concerned about the effects that the expected increases in air temperature and atmospheric vapor-pressure deficits in the twenty-first century might have on the growth of trees. Because the most relevant allometric component controlling water transport in trees is the ratio of biomass allocated to photosynthetic tissue (leaves) relative to water-conducting tissue (sapwood), IALC researchers used published values to test a theoretical model predicting that ponderosa pine trees decrease their investments in leaves relative to sapwood as air temperature and atmospheric vapor-pressure deficits increase (DeLucia 1999). They found that desert-growing ponderosa pine trees in a desert-to-montane gradient of Nevada are likely to have higher rates of water-transport per unit of sapwood than montane-growing ponderosa pine trees because of larger-diameter tracheids in the sapwood (Maherali and DeLucia 2000a, 2000b). Inferences drawn from this study should help managers to select ecologically adapted genotypes of ponderosa pine for wood production or other purposes in warm and dry climates that are similar to those of the southwestern United States.

WATER CONSERVATION BY DRIP IRRIGATION

Traditional methods of irrigating agricultural crops in the southwestern United States have largely been through inefficient flood and sprinkler systems. However, effective irrigation practices and water conservation measures are necessary for irrigated agriculture to remain profitable and economically acceptable in the region. Recent innovations in efficient drip-irrigation technology have enhanced its usefulness (Powell and Wright 1993; Camp et al. 2000). A drip-irrigation system installed at the Agricultural Science Center of New Mexico State University illustrates the use of subsurface drip-irrigation methods for growing alfalfa. This IALC project demonstrates the water savings and economic benefits from applying this system rather than flood or sprinkler irrigation

methods. The reduction in water used for profitable agricultural pursuits helps to restore streamflows and improve available ground water.

WATER HARVESTING AND TREATED WASTEWATER FOR IRRIGATION

Many methods continue to be used to develop water supplies for people living in arid and semiarid regions. Irrigation with saline water, use of treated wastewater, and water harvesting are examples. Investigators in an IALC research effort evaluated the possibilities of successfully growing trees (velvet ash, black willow, Fremont cottonwood, eucalyptus, and Modell pine) near Tucson, Arizona, by irrigating them with combinations of potable water, treated wastewater, and harvested rainwater (Karpiscak and Gottfried 1998, 2000). They found greater survival and initial growth in some tree species when irrigated with treated wastewater combined with harvested rainwater in comparison to irrigating with potable water. However, long-term monitoring of the growth and survival of the trees is necessary before basing management decisions on applying this technology. Whether trees take up harmful constituents in the treated wastewater or whether a soil irrigated with the effluent is adversely impacted also remains to be determined.

URBAN EROSION CONTROL AND STORM WATER HARVESTING

Excessive soil erosion, water allocation, pollution of surface water and ground water, and wastewater collection and treatment are major concerns to the people of municipalities along the southwestern United States–Mexico border. The "twin cities" of Nogales (Arizona) and Nogales (Sonora) share the hydrologic and hydraulic characteristics of a common watershed. The steep hills surrounding Nogales (Sonora) are largely denuded of vegetation and are thus readily eroded during heavy rainfall. Drainages that are normally dry become runoff channels and conveyors of sediment-laden flows that leave deposits on roadways and threaten homes and other buildings. These deposits are rapidly converted to atmospheric dust, resulting in the noncompliance of Nogales (Arizona) with U.S. clean-air standards for particulate matter. The IALC is supporting a demonstration project that illustrates how excessive soil erosion can be controlled structurally by planting native vegetation and using water-harvesting techniques that augment the scarce water supplies.

VEGETATION DYNAMICS AND LANDSCAPE VULNERABILITY TO WILDFIRE

Prolonged drought, high-severity wildfire, and high-intensity rainfall events have a devastating impact on the sustainable use of natural resources throughout the dryland regions of the world. In addressing this critical issue, IALC researchers are integrating remotely sensed seasonal and geospatial vegetation and climatic data and information from soil-erosion plots to assess land degradation and potential recovery after wildfire events. Sites in Arizona, Spain, and Israel are the focus of this assessment; the Arizona site is situated in the historic Rodeo-Chediski wildfire area. The landscape degradation assessments are evaluated in terms of vegetation recovery after wildfire events (Ffolliott and Neary 2003). When fully developed and tested, the predictive model will allow planners and managers to generate representative maps of land degradation and risk of post-fire erosion on watersheds at regional scales, making it possible to focus efforts where risks are the greatest. Identified sensitive or vulnerable sites should have priority in management programs for fire prevention and, when necessary, post-fire mitigation. Furthermore, decision makers will be able to assess the ability of landscapes to support various land uses.

MONITORING IN REMOTE AREAS

Sampling of large rainfall and runoff events and other outlier events is difficult in the southwestern United States and other arid and semiarid regions because of the variable occurrence of these events. Encountering extreme or outlier events on remote and often sparsely monitored watersheds is more likely than on a single instrumented watershed, a situation that compounds this problem (Renard 1970; Singh and Woolhiser 1976; Morin and Sharon 1993). To address this situation, IALC-sponsored researchers explored the feasibility of identifying and analyzing data sets for large rainfall and runoff events occurring on remote and sparsely monitored watersheds to become proxies for information obtained from instrumented watersheds to reduce the time and cost of obtaining long-term data from a single instrumented watershed that might not represent the larger remote area.

Studies conducted on the Walnut Gulch Experimental Watershed in southeastern Arizona have provided insight about how to estimate the character of these outlier events on watersheds without instrumentation. Peak stormflows from

isolated watersheds can be estimated from knowledge of surface water profiles indicated by high-water marks and post-flow stream channel geometries. The level of uncertainty associated with these indirect estimates of peak stormflow was also determined in this study. The researchers concluded that these methodologies could be expanded to improve estimates of hydrologic processes on lands with little or no ground-based monitoring.

DISSEMINATION OF WATERSHED MANAGEMENT INFORMATION

Watershed managers throughout the world are formulating and implementing actions that result in the manipulation of natural and human resources to satisfy specific goals and objectives. Watershed management in the southwestern United States is particularly challenging because water supplies and associated resource productivity levels are limited. In addressing this challenge, watershed management research has led to a better understanding of the hydrology, ecology, and land-use potentials of the region's watershed landscapes (Baker 1999). While this research has helped establish management guidelines to meet the needs of the growing population, the findings obtained are not necessarily widely known or readily accessible. An IALC demonstration project increases the accessibility of these findings to a broader audience, and in doing so helps people to improve watershed management decisions and efficiencies by involving a greater number of stakeholders in the decision-making process. A main part of this effort involved bringing the research information to the interested public through the World Wide Web. Thus, "Watershed Management in the Southwest" (http://www.ag.arizona.edu/OALS/watershed) includes a variety of topics on watershed management practices, displays of accessible baseline data sets, and an interactive learning package on watershed management practices (Baker and Young 2000; Haseltine et al. 2002). A recent phase of this effort involves a coupling of GIS applications to allow users to search, chart or graph, and compare precipitation, streamflow, vegetation, and other watershed-based resource characteristics through a dynamic interface on this useful website.

SURVIVORS IN THE SAND

The IALC supported the development of a video, called *Survivors in the Sand*, prepared by media specialists at New Mexico State University that has increased people's awareness of watershed-based natural resources and their management issues. Conservation, sustainable use, and management of arid and semiarid lands were documented in this 1-hour video through on-site interviews and film archives from the southwestern United States and other arid regions of the world. The conservation of water resources, land reclamation treatments, and sustaining endangered and threatened species are highlighted in the video. There has been widespread airing of *Survivors in the Sand* by public and private television and educational institutions. It has won awards at the New York International Film and Columbus International Film and Video Festivals. The video has generated, and continues to generate, awareness of, interest in, and support for better management of land, water, and other natural resources on arid and semiarid lands.

SUMMARY

Scientific and technical efforts of the IALC to learn more about the ecological sustainability and development of arid and semiarid landscapes such as those represented by the southwestern United States are continuing. Results from these efforts enhance the management of arid and semiarid ecosystems for sustainable use of their natural resources within the framework of maintaining the integrity of the ecological processes involved. Enhancing the level of knowledge related to the soil and water resources in these fragile ecosystems is paramount in the efforts. The importance that the IALC continues to place on water resources in its solicitation of research, development, and demonstration projects has been reinforced by focusing this year's requests for proposals on broadly based water-related themes.

ACKNOWLEDGMENT

Preparation of this paper was supported largely by funds provided to the International Arid Lands Consortium by the Cooperative States Research, Education, and Extension Service.

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