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Arid Lands Research
At The University of Arizona

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About This Booklet

As much as 36 percent of the world's land is arid or semi-arid. And despite the problems posed by scarce natural resources, it is estimated that 15 percent of the world's inhabitants live on this land.

Population continues to grow and the demands for food and energy that are being put on the arid and semi-arid regions are a serious challenge to research and technology. This is especially true for the Third World nations that must learn to manage their environment in order to improve conditions for their people.

The University of Arizona is a recognized leader in arid lands research and is making substantial contributions towards solving some of the problems both in the United States and around the world.

This booklet is a brief introduction to that expertise. It is by no means inclusive. The projects cited are intended to give a feeling for the depth and breadth of the research and its multidisciplinary nature.

The booklet is also meant to show persons interested in the university's unique doctorate program in Arid Lands Resource Sciences the kinds of studies and research opportunities available to them. The doctorate program is described on page 22.

Crops

People have been making the desert bloom for centuries but pressure from population growth, dwindling water supplies and soaring energy costs is forcing a new look at arid land farming.

University of Arizona researchers are deeply involved with improving current cash crops, finding alternative arid land plants and exploring innovative farming concepts for the future.

Cotton, alfalfa, sorghum, wheat, barley and lettuce are some of the economically important crops in Arizona. Research at the *College of Agriculture* is concerned with producing new varieties that are better able to withstand the arid land stresses of drought, high soil salt content and high temperatures.

A short-season cotton, for example, is being developed that would require less irrigation and pesticide use.

While university agricultural research continues to be aimed at helping today's arid land farmers deal with water and energy problems, it is also expanding into new areas as a cushion for the future.

A particularly good example of cooperative research is an effort to domesticate wild plants already desert-adapted and which can contribute to scarce natural resources.

Euphorbia is one such plant.

Cotton, an economically important crop for Arizona

Hydrocarbon-rich latex from Euphorbia

There are some 2,000 species found in just about any climate. They are natural oil wells and produce low molecular weight hydrocarbons similar to crude oil pumped from the ground.

In 1978, the Diamond Shamrock Corporation and the university concluded an agreement to jointly initiate a $2 million study to see if it is agriculturally and economically feasible to transform Euphorbia into a domesticated, renewable energy crop.

The project is being managed by the *Office of Arid Lands Studies* which is coordinating work in about a dozen areas.

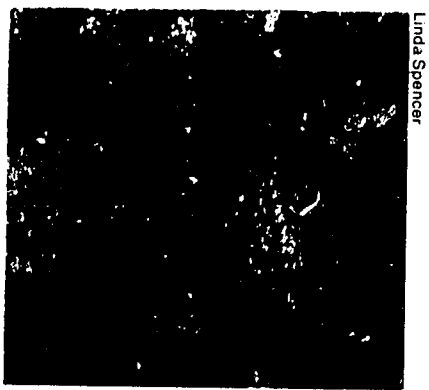
Researchers in the College of Agriculture's *Departments of Plant Sciences, Soils, Water and Engineering, Plant Pathology* and *Entomology* are looking into the problems of Euphorbia agronomics, breeding, pathology, irrigation, fertilization, soil microbiology, harvesting and other aspects of plant domestication.

In the College of Liberal Arts' *Departments of Chemistry* and *Biochemistry* along with the *College of Pharmacy*, researchers are analyzing Euphorbia species to see which are the best hydrocarbon producers; what is the physical and chemical nature of the milky liquid; how do the plants produce the hydrocarbons and what is the best way of extracting them from the plant material.

Plans include the design of a pilot processing plant with a production capacity of 40 barrels per day of crude oil. As the program moves into pilot-scale operations, the *College of Engineering* and the *College of Mines* (Department of Chemical Engineering) will join in the research.

Scientists with the Office of Arid Lands Studies and the Department of Plant Sciences also have played a major role in developing jojoba and guayule as arid land crops.

The peanut-size seeds of jojoba, a bushy desert shrub, contain an oil with an astounding number of properties.



Linda Spencer

Rubber-producing guayule

Oil-bearing jojoba

The university began investigating jojoba in 1972. The work resulted in a jojoba oil industry now operated by the San Carlos Apache Indians in southeastern Arizona.

It also sparked interest among private farmers who have turned jojoba into a small, southwestern business with some 10,000 acres planted commercially in south Texas, Arizona and California.

There are some 30 companies now selling jojoba-based products including hair care preparations, cosmetics, candles and lubricants.

Guayule is not a new arid land crop. It was farmed during World War II for its rubber which is comparable to natural rubber from the hevea tree. The effort stopped abruptly with the advent of synthetic rubber.

But now the cost and supply of synthetic rubber, which is made from petroleum products, is uncertain. And since the United States imports all of its natural rubber, there is concern about its continued availability.

Because of this, guayule is being given a second look as a possible arid land crop that could help make the nation self-sufficient in this strategic material.

Researchers are conducting

breeding trials and compiling a technology assessment of guayule commercialization for the National Science Foundation.

Halophytes are other promising arid land crops being investigated. These are salt-tolerant plants that could become crops for coastal deserts and other regions near salt water to reduce competition for fresh water.

The traditional way of dealing with salt problems has been to breed salt-tolerant varieties of current food crops, but success so far has been limited.

The university's *Environmental Research Laboratory* (ERL) has been taking the opposite approach to the problem. Researchers there have been collecting halophytes growing in salty environments and analyzing them for food value, either for human consumption or as forage.

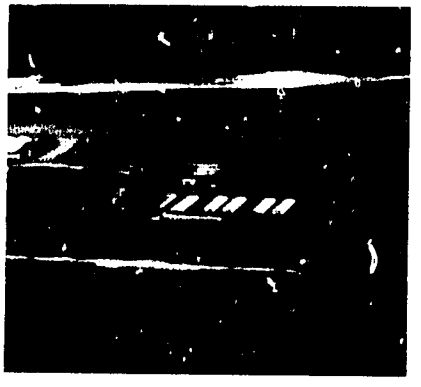
The ERL has headquarters and greenhouses at Tucson International Airport. It also operates a major research facility with the *University of Sonora* in Puerto Peñasco (Rocky Point), Sonora. This is a Mexican shrimp fishing village on the Gulf of California.

Experimental plots of halophytes irrigated with full-strength seawater are growing at the Puerto Peñasco facility. One of the plants has been found to have a protein content between wheat and soybeans.

Seawater irrigation for halophytes

Cultured shrimp

Cooperative research facilities at Puerto Peñasco, Mexico



The ERL is a pioneer in the use of controlled-environment greenhouses to reduce the water requirements and increase the yields of vegetables. One of several arid regions where it has transferred this technology is the Arabian sheikdom of Abu Dhabi which had to import all its fresh vegetables. Now they grow abundantly in the barren sand, receiving all nutrients from a trickle irrigation system inside an environmentally regulated, inflated greenhouse.

In 1973, the ERL and the University of Sonora began a joint project in Puerto Peñasco to adapt the controlled-environment greenhouse concept to the intensive farming of shrimp.

Five years of research into such areas as feed formulation and disease control culminated in the 1978 dedication of a one-acre commercial prototype shrimp farm.

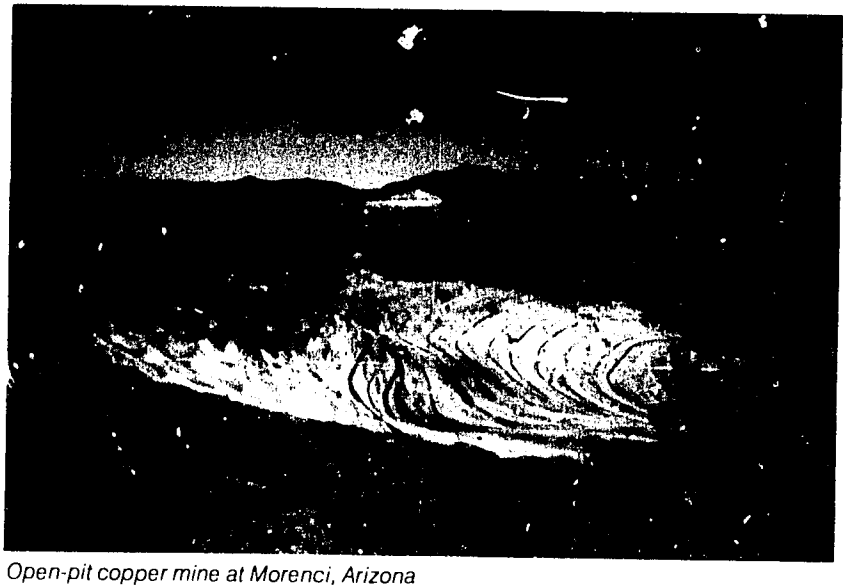
Financed largely by the Coca-Cola Co., the prototype consists of nine narrow, inflated plastic greenhouses. These enclose raceways filled with salt water and three species of gulf shrimp. Even though the prototype is in operation and there are plans for expansion, a major research effort continues in all areas of shrimp cultivation.

Reclamation

When a team of astronauts heading to the moon looked back at Earth to pick out landmarks, they weren't struck by a magnificent mountain range or an expansive prairie. What caught their eyes were the open-pit copper mines in Southern Arizona.

As those astronauts saw, arid lands are slow to recover from human activity.

Concerned with minimizing its impact on these fragile lands, the mining industry is actively supporting research at the University of Arizona to develop more efficient, attractive and economical mine reclamation programs.



Open-pit copper mine at Morenci, Arizona

The university's approach, as in other areas of arid lands research, is a multidisciplinary one with expertise coming from some unexpected areas. The *College of Architecture* is one of them.

There architecture researchers have developed an exciting new approach to the problem. They are tackling mine reclamation before operations begin instead of after the fact.

They use three-dimensional models of the land fashioned out of layered cork. The models are large and depict the terrain on scales of 1" = 1,000' (horizontal) and 1" = 400' (vertical).

With these true-to-life landforms, the architects can reorder the land before mining begins to visualize the best placement of waste material from an aesthetic and functional point of view.

On the cork model, sections can be carved out that are the equivalent volume of waste expected to be generated by the mining operation. This is refashioned into a variety of shapes that fit puzzle-like into the model to simulate placement schemes.

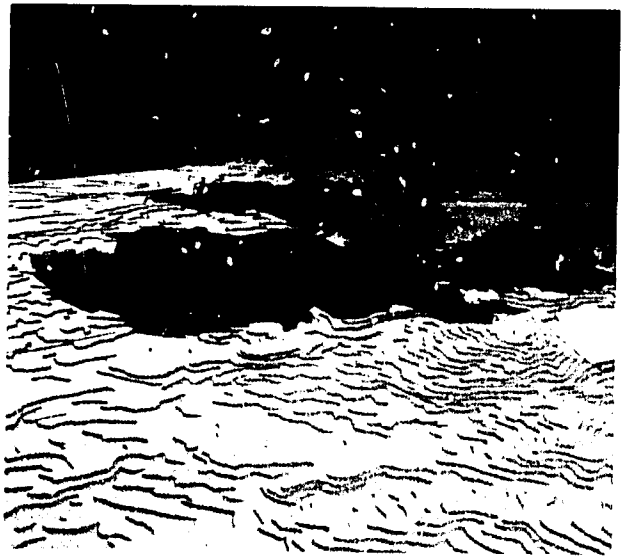
As each scheme is developed, it is computer analyzed for cost at the *Department of Mining and Geological Engineering*.

The technique is being used to develop a reclamation program for a planned open-pit copper mine in the Santa Rita Mountains of southern Arizona. It has been used for a gold mine in Nevada and a molybdenum mine in Washington.

The U.S. Department of the Interior, Office of Surface Mining, selected the university to be one of about 23 regional centers to promote mining research and technology.

This is accomplished through the State of Arizona Mining and Mineral Resources Research Institute directed by representatives from the *College of Mines*, the state *Bureau of Geology and Mineral Technology* and the *Mine Reclamation Center*.

The primary role of the Mine



Layered-cork model of a proposed open-pit copper mine

Southern Arizona copper mines

Reclamation Center is to serve as a focus on university research and technical expertise in reclaiming arid and semi-arid lands such as the novel work being done at the College of Architecture.

The center's advisory committee consists of representatives from the College of Agriculture, the College of Architecture, the College of Mines and the Office of Arid Lands Studies.

Other work being promoted by the Mine Reclamation Center includes:

—the use of satellite pictures and aerial photography to monitor the progress of mine reclamation programs, such as revegetation. Researchers with the *Applied Remote Sensing Program* of the Office of Arid Lands Studies and the *Department of Mining and Geological Engineering* have used computer techniques to automatically map various mining activities in Arizona from satellite pictures.

—a study of the feasibility of reclaiming mined lands with cultivated tumbleweed. There is a possibility that this otherwise obnoxious plant, which prefers to grow on disturbed land, can be converted into fuel. It would be harvested while still green and before it has gone to seed so it can't spread its misery to neighboring farms.

—a major program to convert coal mining spoils on Black Mesa, Arizona, into a water harvesting system that collects rainfall to irrigate nearby farmland. (See section on Water)

In addition to providing a central reference to reclamation research and expertise at the university, the Mine Reclamation Center produces SEAMINFO. This is a cumulative bibliographic data base of references to mined land reclamation literature.

The center also houses the editing offices of SEAMALERT, a quarterly journal of current mined land literature citations that form SEAMINFO.

Energy

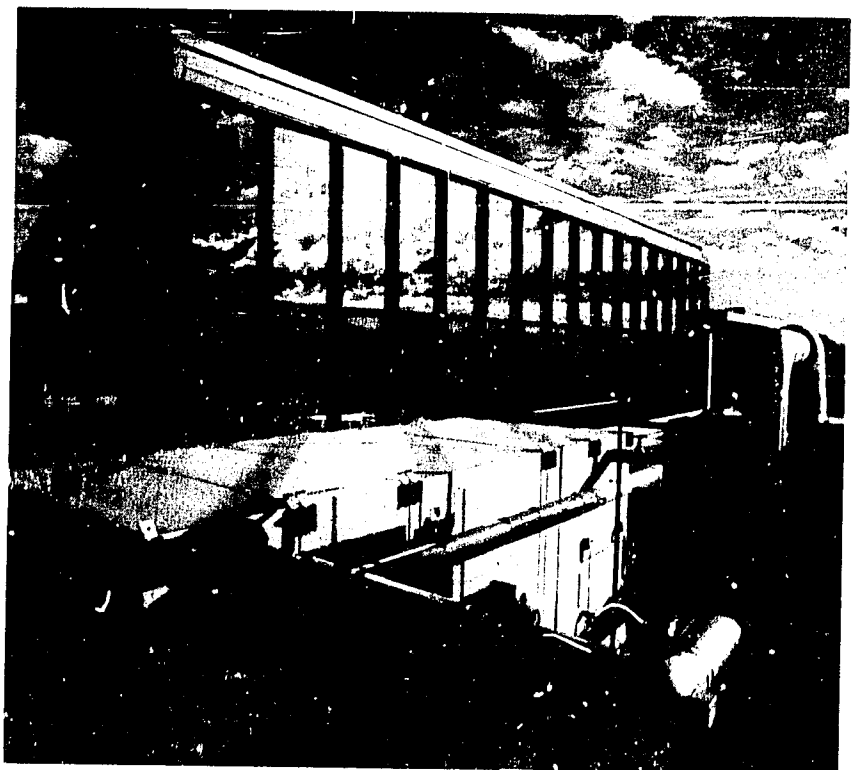
The third floor addition to the University of Arizona Architecture Building is a triangular structure whose south wall is attractively fashioned out of glass and venetian blinds.

The addition, aside from its architectural achievement, is also the university's major solar energy demonstration project. At a cost of $450,000, financed in part by the Arizona Solar Energy Research Commission, it was dedicated March 13, 1979.

The project was designed to demonstrate the innovative research and interdisciplinary cooperation that exists at the university for tackling problems of heating and cooling in an arid environment.

Heat for a 2,800-square foot courtyard enclosed for the project is supplied by the south wall. This is a 72-foot by 16-foot glass enclosed area that is a new concept in solar panels developed at the university's *Environmental Research Laboratory*.

Called the ClearView Collector, it is an imaginative design of venetian blinds sandwiched between sliding glass panes. The blinds are painted a heat absorbing color on one side. When this is turned to the outside, heat builds up between the glass panes and is circulated into the living space by small fans.



Solar addition to the Architecture Building; two-stage evaporative cooler in foreground

Unlike standard solar panels typically mounted on a building's roof, the ClearView Collector can be an integral and attractive part of a building substituting for all or part of a wall. The venetian blinds can be adjusted to control the amount of heating as well as the view to the outside.

In summer, the courtyard is cooled by an evaporative cooler. This uses considerably less energy than refrigeration. And because it works by circulating cool, moist air, it is particularly suited for arid climates.

The evaporative cooler popular in the southwest today is a single-stage device that forces air through water soaked pads.

The cooler on the Architecture Building goes one step further. It

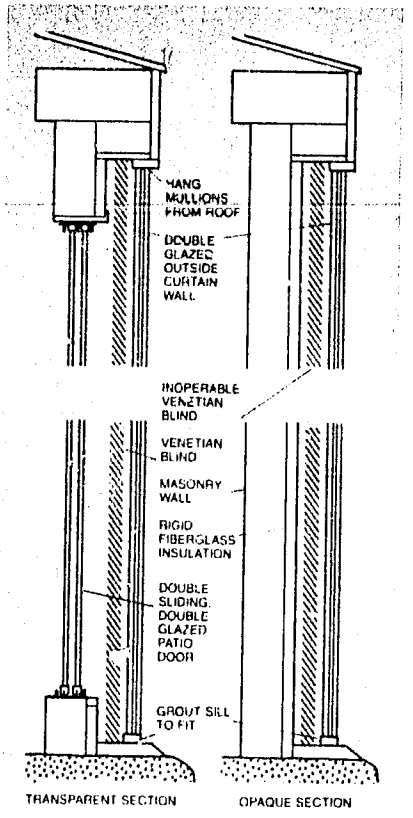
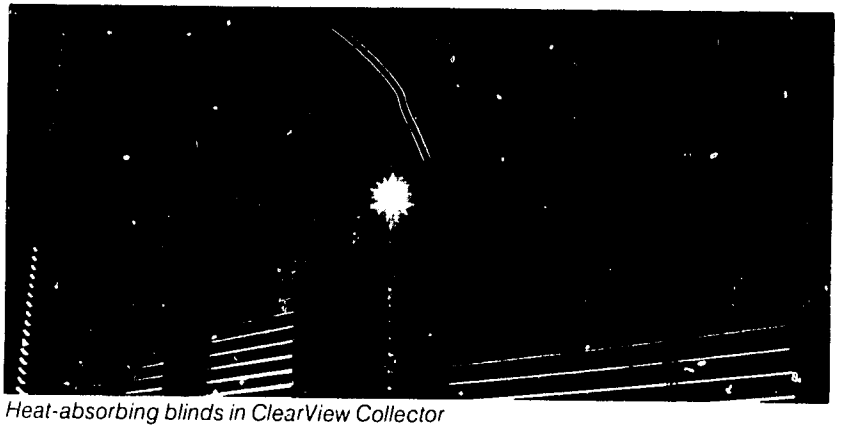
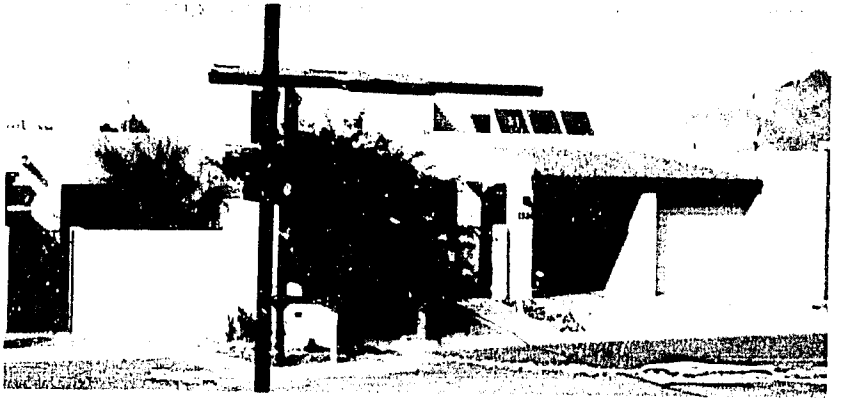


Diagram of ClearView Collector



Heat-absorbing blinds in ClearView Collector

Private solar home in Tucson monitored by the Solar Energy Research Facility



pre-cools the air with a heat exchanger filled with chilled water from a cooling tower. This makes it possible to achieve lower temperatures than possible with a single-stage device. The cost to operate the dual system is midway between a single unit and refrigeration.

Two-stage evaporative cooling is not a new idea. It was used in the southwest during the 1930's but was abandoned with the advent of compact refrigeration units and cheap energy.

The Environmental Research Laboratory has revived the concept and is improving on it as well as on designs for other window solar collectors.

The design for the Architecture Building's modification into a solar energy demonstration project was the result of work by a team of students and faculty from the *College of Architecture*. They worked with the *College of Engineering's Solar Energy Research Facility* which is monitoring the project's performance.

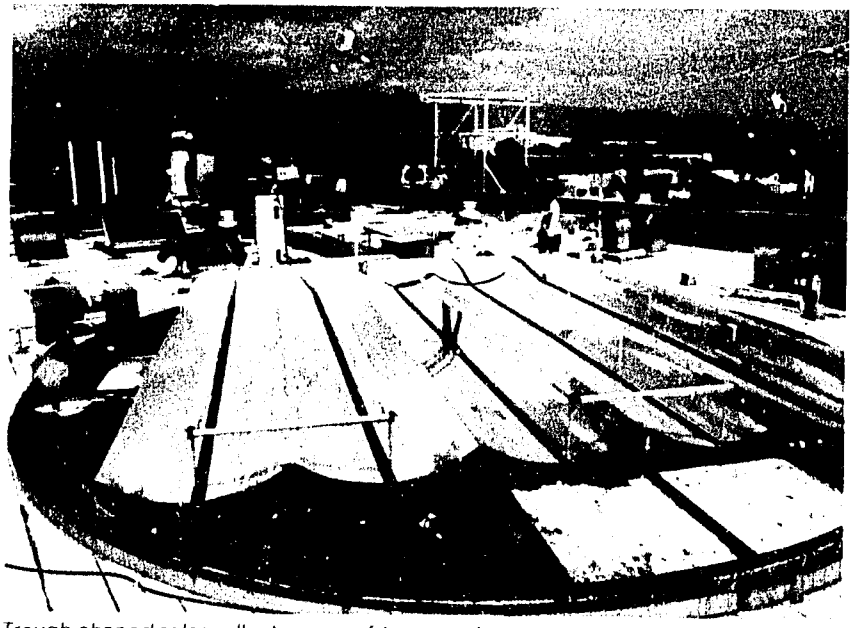
The facility was begun in 1977 because of increasing interest in solar energy studies from a

number of different departments. Researchers needed a central location for testing concepts. The roof of the Civil Engineering Building was converted into an outdoor laboratory for this purpose.

An advisory committee was established with representatives from such areas as engineering, water resources, optical sciences, agriculture and atmospheric physics.

Roof-top experiments at the Solar Energy Research Facility include:

—a carousel concentrating solar collector consisting of several ten-foot parabolic troughs arranged on a circular, plastic foam platform. This wax-impregnated platform floats on water and is turned slowly by a sun-tracking device. Each trough concentrates solar radiation into a narrow line down its middle. Here, photovoltaic cells can be mounted for the direct production of electricity or a water-filled copper pipe can be used to carry away the heat. The trough configuration makes it possible to collect more solar radiation than with a flat plate collector. In addition, floating the system on water does away with friction thus reducing its energy consumption. One possible use for the carousel collector is providing space heating and hot water for a small cluster of residences such as a townhouse complex. The collector could be floated on a reservoir which would act as storage for heat collected during the summer for use in winter months.



Trough-shaped solar collectors, a roof-top experiment

—improved evaporative cooling systems. Researchers with the *Department of Aerospace and Mechanical Engineering* are tackling the problem of inefficient evaporative cooling during humid weather through the use of a liquid desiccant. The outside air is passed through this before going into the cooler resulting in more comfortable living conditions. When the solution becomes saturated, it is dried by heating in a solar collector and reused.

The Solar Energy Research Facility, through the *Department of Mechanical Engineering*, also is documenting the performance of five Tucson solar homes. These were constructed as part of the 1978 Inner City Parade of Homes. The project was in cooperation with the Southern Arizona Home Builders Association, the City of Tucson and the Tucson Gas & Electric Company. Two of the homes have solar space heating and hot water while the other three only have solar hot water. All of the solar equipment was commercially available.

Water

Summer thunderstorm over the Rincon Mountains, Southern Arizona

Sealing water catchment on Black Mesa

Planting tomatoes in Black Mesa garden

During the summer of 1979, the first crop of vegetables and fruit was harvested from a five-acre garden and one-acre orchard on Black Mesa, a coal mining area in northern Arizona.

What made the harvest unusual is that the crops required no groundwater irrigation. They grew solely on rainfall which averages only 11 inches annually. Furthermore, the rainfall was collected by converting nearby coal mining spoils into a water harvesting system.

The University of Arizona project was conceived by researchers in the College of Agriculture's *School of Renewable Natural Resources* and the College of Earth Sciences' *Water Resources Research Center.*

Underwritten by the U.S. Bureau of Mines, it was begun in April 1978 at the Black Mesa coal mining site on the Navajo reservation south of Kayenta, Arizona. With the help of the Peabody Mining Co. and local Navajos, university researchers constructed water collection and crop growing facilities. Traditional methods of revegetating the great piles of overburden are almost futile in an area as dry and windy as Black Mesa. This is a first-of-its-kind attempt at using water harvesting techniques for mine reclamation.

During the seven years prior to construction, researchers and

graduate students conducted computerized hydrological studies of the area, analyzed runoff water quality, selected crops and developed decision-making programs to weigh the cost of various procedures against the benefits.

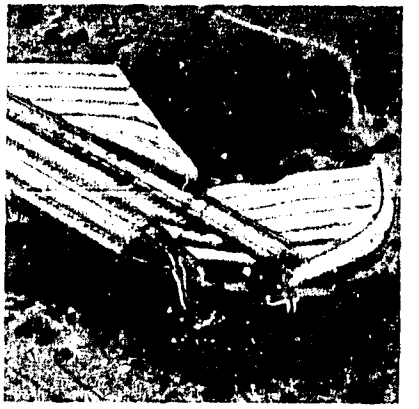
The result was a 10-acre water collection area fashioned out of the coal mining spoils. This feeds three storage ponds, a five-acre garden and a one-acre orchard.

Piles of mining overburden were flattened, compacted and treated with salt to form a terraced collection area. This was topped with a special fiberglass-reinforced asphalt. The collection area directs about 95 percent of the runoff into the storage ponds through a system of ditches.

Water in the ponds, which have a storage capacity of several million gallons, is used to irrigate the garden planted with such vegetables as corn, squash, beans, turnips and lettuce.

The orchard is set up differently. Pear, peach, berry, apple and almond trees are planted in rows between strips of fiberglass/asphalt coated soil graded to direct rainfall towards the trees.

Any excess runoff from the orchard or garden is recycled back to the storage ponds. The water circulation system is powered by a one-kilowatt solar collector that



Water-harvesting system for vineyard

floats on a storage pond. It uses mirrors to concentrate sunlight onto photovoltaic cells which produce electricity directly to maintain the charge on a battery bank.

This system is an improvement on a very old desert farming practice. Canaanites in the Negev Desert, around 2,000 B.C., grew winter wheat with only four inches of annual rainfall. They harvested water by exploiting natural water catchment surfaces and desert washes.

Similar methods are still being used by some Arizona Indian tribes.

Another water harvesting project is making it possible to grow wine grapes in southern Arizona. After four harvests, the grapes appear to be good enough to support a wine industry.

A nine-acre grape orchard was developed at the university's Page Ranch outside of Tucson by researchers with the College of Agriculture's *Department of Soils, Water and Engineering* and the *Department of Plant Sciences*.

The plants grow in rows alternating with sections of treated soil that is graded to direct rainfall to the grapes. The soil is treated with ordinary table salt which seals the surface and prevents weeds from growing.

Excess water flows into a reservoir used for supplemental irrigation during dry periods.

So far, the project has yielded about two tons of grapes per acre with a quality that compares to some of California's best. Researchers have grown such red grape varieties as Cabernet-Sauvignon, Gamay and Zinfandel. White varieties have included Chardonnay, French Colombard and White Reisling.

It appears that Italian grape varieties such as Barbera, which do not grow well in California, are particularly suited to Arizona.

New project additions include a solar-powered pump for irrigation and an experiment to see if aluminum beer cans can be used as an inexpensive evaporation suppressant for the storage pond.

Water harvesting research is aimed at reducing the demand for groundwater.

Harvesting grapes at experimental vineyard

In the Tucson basin, groundwater is being pumped by farmers, industry and cities at an alarming rate. It has been estimated that this pumping is removing about two-and-a-half times the amount of water naturally replenished annually.

Because of this dependency on groundwater, a major effort is underway at the university to better understand groundwater supplies and to quantify natural recharge.

Since 1971, researchers in the College of Earth Sciences' *Department of Hydrology and Water Resources* and the *Department of Geosciences* have been sampling and analyzing rainwater, snow, streamflow and groundwater for the presence of stable chemical isotopes picked up from the atmosphere. The ratios of these isotopes, such as deuterium/hydrogen and oxygen-18/oxygen-16, vary with the season and location. These isotopic "thumbprints" are being used to make a quantitative estimate of the volume of recharge entering the Tucson basin aquifers.

So far the researchers have found that winter precipitation is much more effective in recharging groundwater than summer precipitation, even though there is more of the latter.

It is anticipated that these studies can be applied to other basins in the southwest.

Climate

When climate shifts, arid and semi-arid lands can be especially hard hit.

A period of unusually wet years may suddenly return to what are normal, drier conditions. Marginal lands farmed and grazed during the good times fall barren and famine sets in.

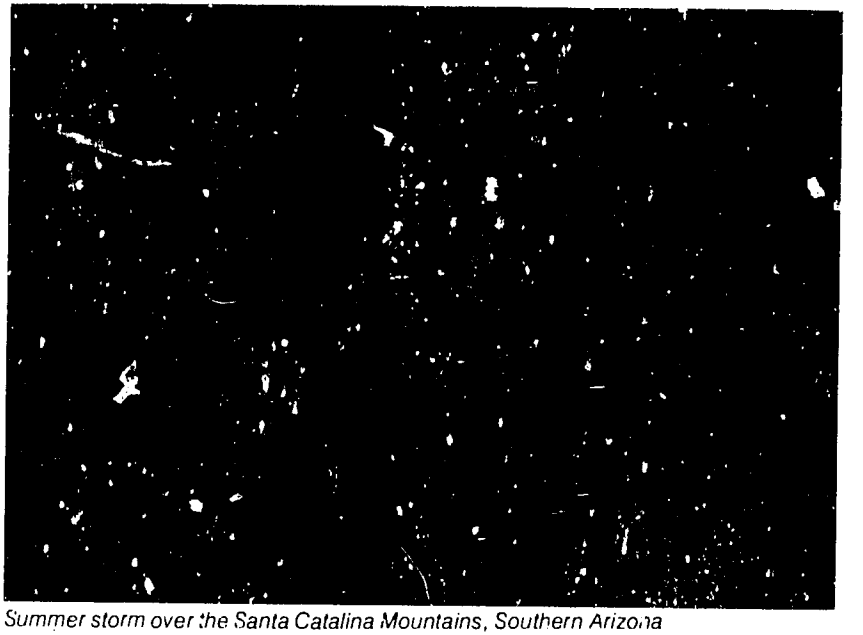
It happened along the Sahara.

At the University of Arizona, researchers are trying to understand how and why climate changes. While it may not be possible to accurately predict future changes, it is possible to use this knowledge to better plan for what might happen.

This is extremely important for developing nations where unexpected climate changes can have a devastating effect on agriculture pushed to its limits. In addition, severe changes can disrupt trade, economics and politics on a global scale.

At the College of Earth Sciences' *Laboratory of Tree Ring Research*, the only one of its kind in the world, scientists are succeeding in decoding the climate information that is stored in the annual growth rings of trees.

This relatively new science of dendroclimatology already has revealed insights into how climate has behaved in the past — information that is vitally important to understand how it might behave in the future.



Summer storm over the Santa Catalina Mountains, Southern Arizona

Dry lake at Willcox, Arizona

Each year a tree builds a new layer of wood just under the bark. The layers form a distinctive pattern of rings in cross-section. The formation of each new ring is controlled by a number of factors including the prevailing climate.

University tree ring scientists have developed computer techniques to remove this climate information by analyzing the rings' size, structure and chemical composition and use it to reconstruct past conditions as far back as the age of the trees sampled. This is often several centuries.

One group of lab researchers has been able to reconstruct season-by-season temperature and precipitation records for North America going back to the early 1600's. These reveal, for example, that the West was drier, and the East wetter in the past than in the 20th century.

Similar tree ring data has been used by other lab scientists to reconstruct a history of drought in the western half of the United States.

The scientists found, quite unexpectedly, that the amount of land under drought conditions in the past has been expanding and contracting in harmony with the 22-year solar cycle (a double 11-year cycle). This apparent solar connection may be useful in estimating the risk of drought in the future.

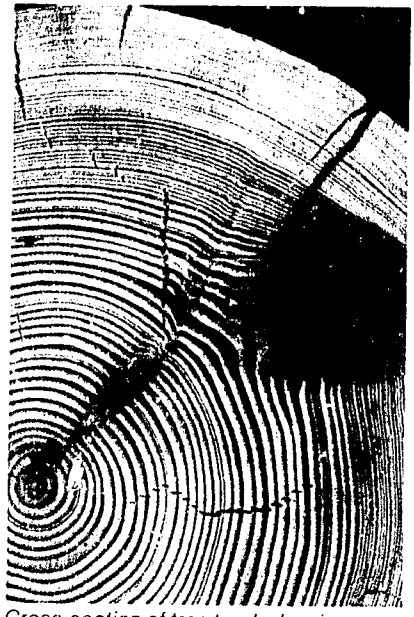
Tree ring climate data bridges the gap between historical weather records and such things as fossils which contain climate information from thousands and millions of years ago.

Researchers in the College of Earth Sciences' *Department of Geosciences* are using fossil and geological information to reconstruct climate in the southwest during the last two million years.

One team, for example, has been analyzing the contents of pack rat middens. The plant material in these middens, which have been found as old as 20,000 years, represents the local flora and can be used to show how vegetation has changed with time. From this, climate can be inferred.

These studies and others clearly show that between 13,000 and 8,500 years ago, the southwest underwent a dramatic shift in climate. The vegetation changed from woodland to sparse desert shrubs indicating a shift from cooler, wetter conditions to the present arid climate.

This is further supported by geological evidence being investigated by other department scientists. They found that as the protective cover of the land disappeared large-scale erosion took place. This is seen in rock deposits of that time.



Cross-section of tree trunk showing annual growth rings

The physics behind climate is best probed with computers and major investigations into modeling Earth's atmosphere are underway in the College of Liberal Arts' *Department of Atmospheric Sciences*.

This research demonstrates the complex nature of the atmosphere and why understanding climate change, let alone predicting it, is not going to be easy. The studies also show the powerful role that deserts play in powering atmospheric circulation. They reflect 20 to 30 percent of the incoming sunlight compared to the 10 to 20 percent reflected by grasslands.

People

Zinder is a province in south central Niger. It may get enough rain to grow crops three out of five years. The people living in this 160,000 square kilometer region have never been counted in a census.

The Yemen Arab Republic (North Yemen) is one of the 12 least developed countries in the world. The first high school graduate was produced less than a decade ago.

Niger and Yemen are two examples of developing nations where University of Arizona expertise in arid lands research has been used to help the people deal more effectively with the harsh realities of their land and improve their living conditions.

Moreover, the important lessons being learned in these underdeveloped areas are being used to help people living in the arid regions of the United States, especially southwest Indian tribes, to improve the quality of their land and lives.

The Niger project, which concentrated on the province of Zinder, was carried out from 1976 to 1979 in collaboration with the Niger government. It was begun with an initial visit by a study group headed by a government specialist with the *Department of Political Science*. It included the director of international agriculture programs with the *College of Agriculture* and a solar energy expert with the *Department of Nuclear Engineering*.

Market day in Zinder, Niger

Eventually, the project tapped university expertise in such areas as marketing, anthropology, hydrology, ecology, remote sensing, and urban planning.

University researchers concentrated their studies in four areas they believed posed the most significant barriers to development:

—water management: rainfall data was collected and analyzed and the groundwater supply was studied and its uses determined.

—energy flow: the rate of consumption of firewood, uses and supply were charted.

—marketing: the prices and supplies of important goods including the dietary staples of millet and sorghum were analyzed.

—attitude toward change: The people's feelings about change, their perspectives, aspirations and needs were explored through a public opinion survey in three villages.

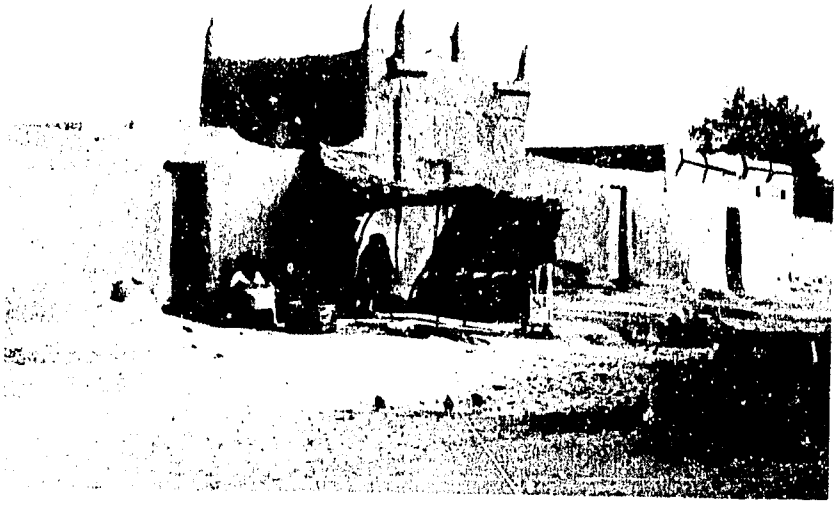
All this information was woven together into a final report to the Niger government showing the country's potential problems and proposing a plan for development over 10 years that could enhance the people's diet and income. The plan is based on the development of a cattle industry managed properly so that marginal lands are not overgrazed and turned into wastelands.

The Niger project was coordinated by the university's *Arid Lands Natural Resources Committee* which grew out of a five-year program financed by the U.S. Agency for International Development. Through AID grants, the university increased its capabilities for providing assistance to developing nations that need help with natural resource planning in arid and semi-arid regions.

The committee has representatives from biology, public administration, women's studies, family and community medicine, hydrology, arid lands studies, agriculture, geosciences, engineer-

Nigerian cattle

Turreted roof of a Zinder home



ing, renewable natural resources and anthropology.

In addition to being a mechanism for promoting interdisciplinary arid lands research, the committee is also the advisory body for federal Title XII funds. This money was made available through a 1975 Congressional amendment to the Foreign Assistance Program.

Title XII funds are being used at the university for such programs as language training for faculty and staff who will be working in foreign countries and increasing faculty expertise in areas of arid lands range management and livestock production, small-scale farming systems and the problems of women in developing countries.

The Yemen project was the first phase of an agricultural development program sponsored by the U.S. Agency for International Development. It was directed by the College of Agriculture's *Department of Plant Sciences* for the Consortium for International Development.

This is an organization of 11 western universities, including the University of Arizona, with expertise in solving arid land problems.

The Consortium was established in 1968. Its goal is to provide better aid to developing countries through a cooperative university effort.

Remote Sensing

Examining the Earth from above its surface through remote sensing techniques is an important part of research at the University of Arizona and is becoming increasingly important in arid lands studies.

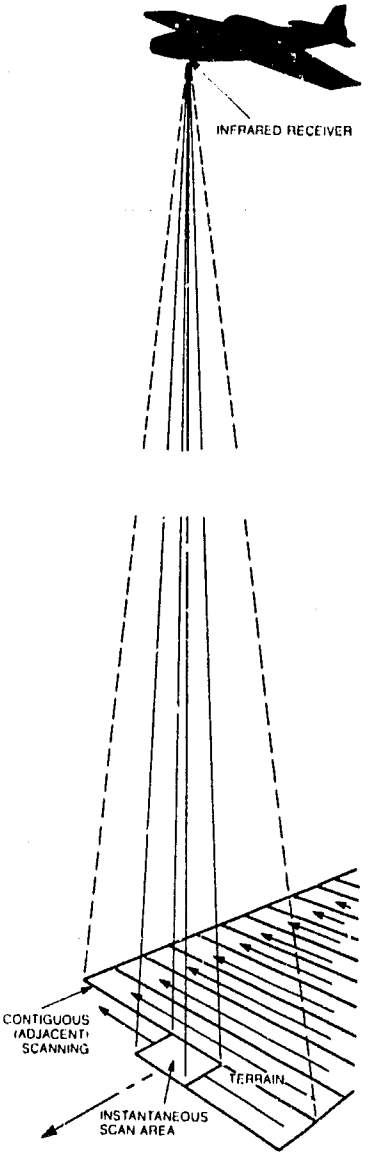
Scientists and engineers in more than a dozen different disciplines rely on such things as aerial photography and satellite imagery to aid them in their work.

Because of the growing use of remote sensing in all areas of research, the university-wide *Committee on Remote Sensing* was established in 1975 to coordinate the effort, promote interdisciplinary studies and develop an academic graduate-level program in remote sensing.

Among the areas of expertise represented by the 13 committee members from eight university colleges and divisions are agriculture, geosciences, arid lands studies, atmospheric sciences, engineering, optical sciences, and geography.

At the *Optical Sciences Center*, research programs are aimed at better understanding the potential and limitations of remote sensing devices and exploring new methods of collecting and analyzing data.

Applied remote sensing work ranges from monitoring mine reclamation programs to charting urban sprawl. In particular, remote sensing is used in a variety of arid lands studies such as:

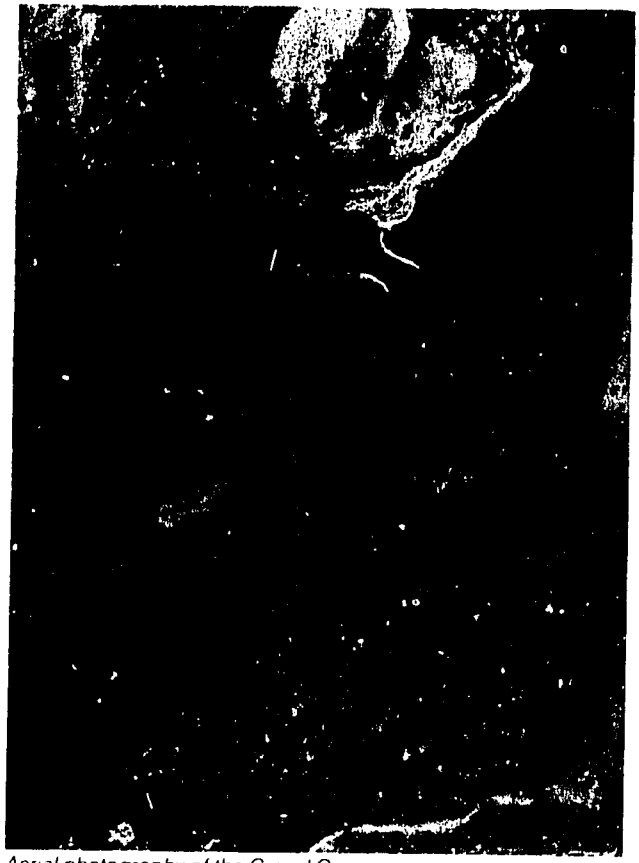


Infrared scanning by aircraft

—range management. Proper use of rangeland in arid and semi-arid climates is crucial. Overgrazing can quickly destroy the land for future use and initiate the process of desertification. Range management specialists with the *School of Renewable Natural Resources* are using remote sensing to plan proper grazing programs in Arizona and to develop soils and vegetation maps. Remote sensing data have been used to plan revegetation strategies for land already deteriorated and to better distribute livestock based on an area's water resources.

—crop monitoring. Remote sensing is quickly becoming an important tool for assessing crop condition. Scientists with the *Department of Plant Pathology* are experimenting with it for the early detection of disease in some Arizona crops before signs of distress appear.

—archaeology. The prehistoric inhabitants of the Sonoran Desert developed sophisticated water conservation and controlled erosion methods in order to farm the land. Some of these agricultural systems are in central Arizona. Barely visible from the ground, they are being studied with a remote sensing program conducted by archaeologists with the



Aerial photography of the Grand Canyon

Arizona State Museum located at the university.

The university became involved with remote sensing in 1970 when the *Office of Arid Lands Studies* received a grant from the U.S. Department of the Interior to manage the Arizona Regional Ecological Test Site.

Many other programs across the country have been patterned after this program which, among other things, established a multidisciplinary resource and environment team in Arizona capable of using remote sensing data to define the ecological relationships and problems in this region.

The *Office of Arid Lands Studies* has a continuing grant from the National Aeronautics and Space Administration to apply remote sensing data to state and local government needs, such as planning, zoning and environmental monitoring.

Remote sensing research is supported by a library of remote sensing imagery and several laboratories and facilities available for multidisciplinary projects. These house a wide range of equipment for such work as automated information extraction, atmospheric measurements, image processing and color display.

Livestock

Hot, dry climates are particularly stressful to livestock, decreasing their food production and fertility.

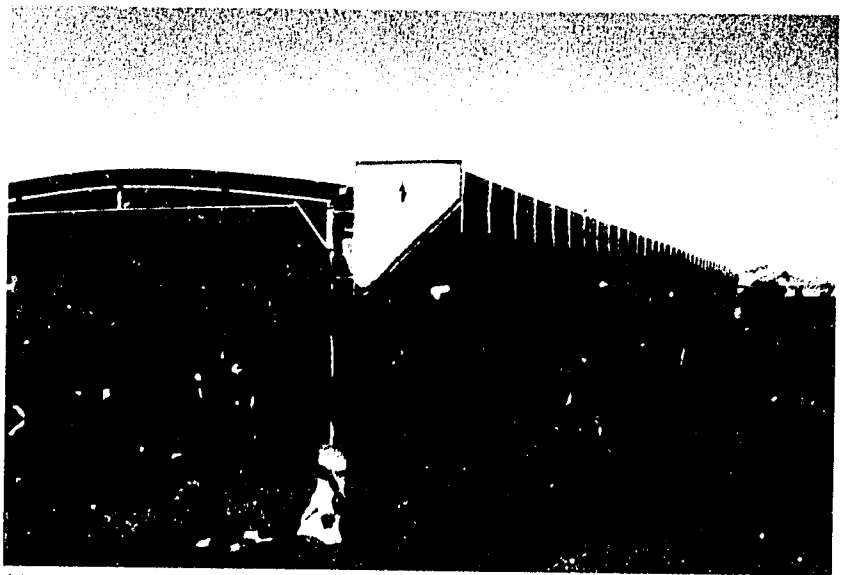
Research programs at the College of Agriculture's *Department of Animal Sciences* concentrate on combating this problem to improve livestock production in the United States and in developing nations.

Studies focus on poultry, dairy cattle and beef cattle and include investigations into nontraditional livestock.

Keeping meat and egg production at a maximum during hot summer months has meant high utility bills for cooling poultry houses. University animal scientists are looking at the problem from the other direction: they are using less cooling and offsetting the effect of increased temperature on production by changing the animals' diet.

Preliminary success has resulted from adjusting the diet's amino acids which are needed to combat stress and increasing its energy density to compensate for eating less because of the higher temperatures.

Dairy cows' milk production and fertility also suffer during hot summer months. But animal scientists and researchers from the *Department of Soils, Water and Engineering* have been able to overcome this with evaporative cooling systems for the animals' conventional open shade areas.



Livestock shade stall with evaporative coolers

Other studies are looking at ways to reduce the cooling needs of cows without affecting their production by cooling only during milking rather than continuously.

Apparently this is enough time for heat accumulated in the animals' surface to radiate out before it has time to move internally and affect physiology.

Research is underway to understand how these animals cycle heat through their body.

For the past 25 years, the Department of Animal Sciences has had a cooperative program with the San Carlos Apache Indians to improve the tribal beef cattle herd through improved management programs.

An important finding of this project is that supplemental feeding for grazing cattle is not always necessary. It seems that the animals have a tremendous capacity to compensate for cyclic changes in food availability. Rapid fat storage when food is abundant appears sufficient to carry them through the months when rangeland food is scarce.

Rabbits are adaptable to arid lands. In fact, wild rabbit is a source of food in many arid regions. University researchers are looking into the possibility of cultivating these animals as a potential "backyard" farming enterprise that could be a significant source of food for families in developing nations.

OALS

The University of Arizona's Office of Arid Lands Studies manages a wide range of programs and university-wide research projects on arid lands problems. During fiscal year 1978-79, these were supported by nearly $2 million in grants and contracts.

The office began in 1958 as an informal, interdisciplinary collaboration of faculty and research associates interested in identifying and solving the pressing problems in the world's arid and semi-arid regions.

It was made a formal university office in 1964 when the U.S. Army Research Office asked it to administer a $250,000 grant to prepare "An Inventory of Geographical Research on World Desert Environments."

Since then, the Office of Arid Lands Studies has expanded its role to include the management and administration of the following:

— Arid Lands Resource Sciences Ph.D. Program: Since 1968, the office has administered this unique program. It is a broadly based, interdisciplinary degree for the mature student whose academic and career goals cannot be attained through traditional academic programs.

—Arid Lands Information Center: This is a primary university resource providing computerized storage and retrieval systems for information on such arid lands topics as water resources, vegetation, surface environment and mined land reclamation. Beginning in January 1980, it will join the Commonwealth Agricultural Bureaux, United Kingdom, in publishing a new international journal called "Arid Lands Abstracts." This monthly publication is expected to provide over 5,000 abstracts of arid lands literature annually.

— Applied Remote Sensing Program: Begun in 1974 with support from the National Aeronautics and Space Administration, the program produces natural resource inventories and maps through the use of satellite imagery, aerial photography and ground-truth investigations. It is also a public service organization providing information and training to planners in remote sensing techniques and applications.

—Laboratory of Native Development, Systems Analysis and Applied Technology: This facility was established in 1976 with support from the U.S. Department of Commerce's Economic Development Administration. It provides technical assistance to southwest Indian tribes in natural resource assessment and development.

—Research Programs: The office administers several large grants which include a number of university departments. The studies focus on possible new arid land crops such as: Euphorbia which yields hydrocarbons similar to crude oil; tumbleweed which may be converted into a fuel; jojoba whose seeds yield an oil similar to the oil of the endangered sperm whale; and guayule which produces a high quality rubber comparable to imported hevea rubber.

Tucson in the spring—blooming cactus

Doctorate

The University of Arizona Arid Lands Resource Sciences Program offers a broadly based, interdisciplinary Doctor of Philosophy degree.

It provides degree opportunities for unusually gifted, mature students whose goals do not fit into the traditional academic degree-granting structure, but who have the qualities and experience to make outstanding contributions to solving worldwide arid lands problems.

Applicants must demonstrate the research skills needed to design and complete a rigorous program and show evidence of competence beyond that expected of the ordinary doctoral candidate. The program is designed to offer flexibility so that such students can acquire an unusual breadth of education.

Proposed individual programs that are only variations of scholarly pursuit leading to doctoral degrees in traditional disciplines are not accepted for the Arid Lands Resource Sciences degree. Students wishing to pursue such programs are referred to the appropriate department for required course work to acquire a more traditional doctorate.

Each candidate for the doctorate in Arid Lands Resource Sciences will have a major adviser from his or her special field of interest and a specially chosen faculty committee to supervise academic work.

The tailor-made program may take elements from graduate curricula in the natural, agricultural, and social sciences along with other related courses and fit them into an innovative and imaginative course of investigation. Such a program could consist of any appropriate combination of graduate courses from various university departments.

Each student's program design is as unique and original as his or her research; no specific course work is required of all candidates for this degree. The student must, however, satisfy all general university requirements for the Doctor of Philosophy degree as set forth in the graduate catalog.

The Arid Lands Resource Sciences doctorate is not the type of degree program one should pursue if research and teaching are career goals. The candidate is faced with more areas of investigation but in less depth. Because one would emerge as a generalist with this degree, a candidate is encouraged to develop this program after completing a Masters degree or in conjunction with a strong minor.

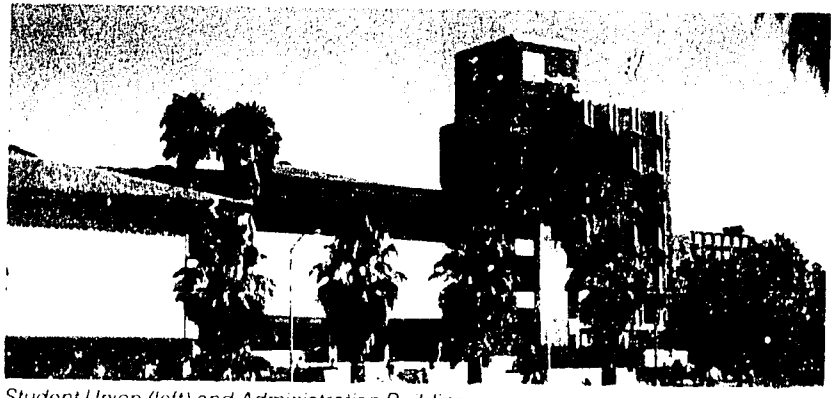
The following is a general outline of a program pursued by an Arid Lands Resource Sciences candidate who has clear long-range goals to participate in developing the economic potentials of arid lands resources in the less developed regions.

Old Main, 1891, first university building

Her undergraduate degree is in anthropology and includes a fair amount of work in physical sciences and mathematics including calculus, differential equations and numerical analysis.

Her graduate program includes three courses in anthropology that provide additional strength in arid region development; four courses in geography that provide a background in arid lands geography and resource management and development. Additional courses explore environmental analysis, international development, bioclimatology and arid lands resource sciences.

Her minor is in economics which includes course work in economic development, natural resource economics as well as micro- and macro-economics.



Student Union (left) and Administration Building

Why study at the University of Arizona?

From its inception, most University of Arizona applied research has focused on arid lands problems since more than 90 percent of Arizona is semi-arid or drier.

Within Arizona's boundaries are counterparts of the natural features of all arid lands except such cold continental deserts as the Gobi in China and such cool coastal areas as the Chilean Atacama; no desert area of comparable size contains a greater variety of arid landscapes.

In parts of Arizona average annual precipitation is less than 3.5 inches comparable to As Samawah, Iraq. In other parts, sheep graze and crops grow where temperatures dip to minus 32 degrees Fahrenheit comparable to southern portions of cold Asiatic deserts.

Climatic diversity in Arizona is caused mostly by the scattered mountains and tabular highlands, conditions similar to those of northern Algeria. The processes and results of weathering, erosion and deposition have been examined at less than 200 feet above sea level along the Colorado River, just as they have been studied along the Nile. On the other hand, Colorado Plateau elevations are comparable to portions of the Iranian plateau, the central Sahara and the Kalahari.

Since Arizona from prehistoric times to the present has experienced a greater variety of human activity than any other desert region, it is a useful area for drawing human-use analogies. Semi-nomadic Navajo sheep grazing is much like that of the Kirghiz of Asia and the Berbers of Africa while flood agriculture is practiced both in Arizona by several Indian tribes and in the Sahara.

The 1980 Arid Lands Resource Sciences Ph.D. Advisory Committee is chaired by Dr. Jack D. Johnson, Director of the Office of Arid Lands Studies.

Other committee members are:

Dr. Herbert E. Carter, Head, Department of Biochemistry

Dr. Leonard W. Dewhirst, Professor, Department of Veterinary Science and Associate Dean, College of Agriculture

Dr. Theodore E. Downing, Assistant Professor, Anthropology

Dr. Daniel D. Evans, Professor, Department of Hydrology and Water Resources

Dr. David A. Mouat, Assistant Professor, Department of Geography, Regional Development and Urban Planning and Applied Remote Sensing Program

Dr. Terah L. Smiley, Professor, Department of Geosciences

Dr. Elinor C. Terhune, Assistant Director, Office of Arid Lands Studies

Dr. Ervin H. Zube, Director, School of Renewable Natural Resources

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