2002 ANNUAL REPORT

Colorado Agricultural Experiment Station

Colorado State University

Knowledge to Go Places

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This annual report summarizes the results obtained by a selected group of the more than 140 ongoing research projects supported by the Agricultural Experiment Station at Colorado State University. The Agricultural Experiment Station is an integral component of Colorado State University, your land-grant university, and it is committed to conducting research on the agricultural and natural resource needs of the people of Colorado. Our mission is to support research leading to an agriculture that is economically viable, environmentally sustainable, and socially acceptable. The Agricultural Experiment Station research efforts extend across the entire campus involving faculty and staff from more than 20 academic departments in 6 colleges. In addition to projects conducted by faculty located at Fort Collins, we have a network of off-campus research centers conducting research to meet agricultural production needs in different regions of the state. To address the complex problems facing agriculture, it is essential that academic departments and off-campus research centers work in concert with each other to solve problems through interdisciplinary efforts.

An initiative was funded by the Colorado legislature for the 2001-2002 fiscal year to enhance funding for research on invasive plants, better known as noxious weeds. Invasive plants are a serious threat to the productivity of range and forest lands as well as privately owned lands in Colorado. We are extremely pleased that the Colorado legislature funded the first year of a phased initiative to provide base funding for research on issues facing Colorado agriculture. Eight research projects on invasive plants have been initiated by faculty in weed science, range science, chemistry, ecology, biology, and entomology. In addition to applied research on methods of controlling noxious weeds, basic studies are being conducted to evaluate the genetics of weeds and ecological processes controlling the invasiveness of particular species. The base funding increase provided by the Colorado legislature for invasive plant species research will significantly enhance our efforts to address the economic and productivity impacts of these plants. Appreciation is extended to all who supported our efforts to obtain additional funds for this program enhancement.

The results of research shared in this report represent the diversity of efforts conducted by faculty supported by the Agricultural Experiment Station at Colorado State University. Many of the research projects described receive significant support from state, regional, and federal funding agencies. Each year, the Agricultural Experiment Station compiles a report on external funding of our agricultural and natural resource research program. The total external funds received by our faculty exceed $20 million per year. Thus, funds provided by the state of Colorado leverage at least a two-fold increase in external support for our research programs. We are proud of our faculty and their abilities to conduct relevant and important research.

I hope you enjoy this report. Please contact me if you have any questions concerning the research program supported by the Agricultural Experiment Station at Colorado State University.

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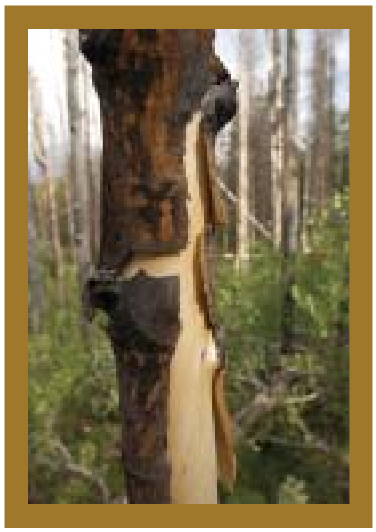
Taking a Higher View

Using Airborne Imaging to Predict and Research Wildfires

For years, Indy Burke, professor of forest sciences and one of a handful of University Distinguished Teaching Scholars, has concentrated her research on the communities of life found below ground in the shortgrass steppe of the Great Plains.

Recently, she's been going into space with a different kind of research.

Burke and her team are launching new research to develop and evaluate data generated from satellites and other airborne systems to predict and manage wildfire risk in the Rocky Mountain West. In addition, the team hopes to evaluate how fire contributes to the release of carbon into the atmosphere.



Considering the catastrophic forest fires that have swept through Colorado and the West this summer and in past years, the research may help reduce the impact of wildfires, which have affected property and water supplies as well as the forest landscape.

Burke and her colleagues hope to be able to predict the behavior and intensity of fires to help agencies and other organizations minimize wildfire risks with fuel treatments and prescribed fires. In addition to funding from the Agricultural Experiment Station for field research, a three-year grant from NASA is being used for imaging technology and technical support staff.

A co-principal investigator is Merrill Kaufmann, affiliate professor of fire ecology at Colorado State and research scientist for the U.S. Forest Service. Kaufmann has long-term data sets of Cheesman Reservoir, another key study area for the team, and is contributing other valuable input for the research project.

"The goal is to use satellite or airborne imagery to find out the location and types of forest fuels – wood that is likely to burn – before fire occurs," Burke says. "We've already gathered a lot of information to analyze. We had several overflights of the Hayman Fire area before the burn and several afterward, and we'll continue to gather data using many remote-sensing systems, including one called lidar."

Lidar is an acronym that stands for Light Detection and Ranging. Similar to radar, lidar systems transmit and receive electromagnetic radiation, but use laser (light) rather than radio waves.

Graduate student Jason Stoker, who is in the forest sciences program, has made enormous progress in proving that the technology works for assessing trees in studies made before the Hayman Fire happened, Burke says. She also gives credit to another graduate student and valued member of the team, Sonia Hall, who is in the University's ecology program.

"Now we can attempt to answer the questions: Could we have predicted where the (Hayman) fire was going to go and how it would have burned? What kind of information are we missing? What data do we need to predict fire behavior?" says Hall.

The team will couple several types of imagery with another high-tech system called FARSITE, a computer program that simulates the spread and behavior of fires under conditions of variable terrain, fuels, and weather. While FARSITE often is used on a real-time basis during fire suppression activities, the team will couple remotely sensed data with FARSITE modeling on landscapes before prescribed burns and compare the output to experimental results.

"One key question is: How much carbon is lost after a fire and put into the atmosphere as carbon dioxide?" Burke says. "We want to find out whether the same remote-sensing data sources can be used to quantify the carbon consequences of wildfires and wildfire suppression.

"That part of the research speaks to the broader science and global-scale management question of the role of fire in greenhouse gas concentrations, like CO_2. Fuel is made of carbon stored on the earth's surface – three times as much carbon is found in vegetation and soil as is found in the atmosphere. And while it's stored on the surface as fuels, once that fuel is burned, the carbon in it is carried aloft as carbon dioxide – a greenhouse gas."

Burke's team includes Thomas Vonder Haar, University Distinguished Professor in the Department of Atmospheric Science and co-principal investigator on the NASA grant and on the Agricultural Experiment Station project.

"Tom has been on the leading edge of remote-sensing technology for his entire career," Burke says. "It's an exciting time to be in this area of research and to share discoveries with team members."

Digging Deeper

Subsurface Drip Irrigation Boosts Efficiency and Crop Yields

Kevin Larson is going underground to make better use of water. He's testing a subsurface drip irrigation system on row crops at the Plainsman Research Center in Walsh. "I've never seen such consistency and high yields in the plots," he says, "and it's with less water." Larson is testing this irrigation method on corn, grain sorghum, sunflowers, and, in the future, soybeans. Drip irrigation isn't just a pipe dream, either, since a new government aid program makes it attractive for farmers to invest in the water-efficient system.

"Subsurface drip irrigation is the next quantum leap in irrigation efficiency," says Larson. Since water never reaches the soil surface in a subsurface drip irrigation system, there is almost no evaporation loss. This compares to 50 percent efficiency for furrow irrigation, 75 percent for sprinkler, and a maximum of 90 percent for a "low-energy precision application" sprinkler systems.

Subsurface drip irrigation has a network of perforated tubing, called drip lines, buried one foot deep and five feet apart. Each drip line runs between two rows of crop. The drip lines are divided into zones that are supplied well water. Similar to a home sprinkler system, a controller and a system of valves turns the supply of water on and off to each zone on a programmed schedule.

For more than a decade, Larson has been experimenting with limited irrigation methods with furrow and sprinkler systems to make even better use of water. Limited irrigation is used to create an economic balance between the costs of irrigating versus the reduction of crop yield if less water is applied. Farmers have a pretty good idea of how much water is necessary to get maximum yield from their fields. However, with high energy costs, Larson has found it may be more profitable to pump less water than required on a field. The loss in crop yield is offset by the cost of the water. Now Larson is applying limited irrigation with drip as well. So far, he thinks the crops respond well with limited irrigation applied with drip.

Besides efficient use of water, drip offers several other benefits. With subsurface drip irrigation the entire field is irrigated. Center pivot irrigation systems do not water the corners of the field–about 20 percent of the crop area. Also, because subsurface drip irrigation waters the plants up to four times per day, they are less stressed. Crops under a center pivot only may be irrigated once a week. Less surface water also means potentially less weed germination. It's also easier to deal with any weeds, since the farmer can run equipment in the field at any time because it never gets muddy from watering.

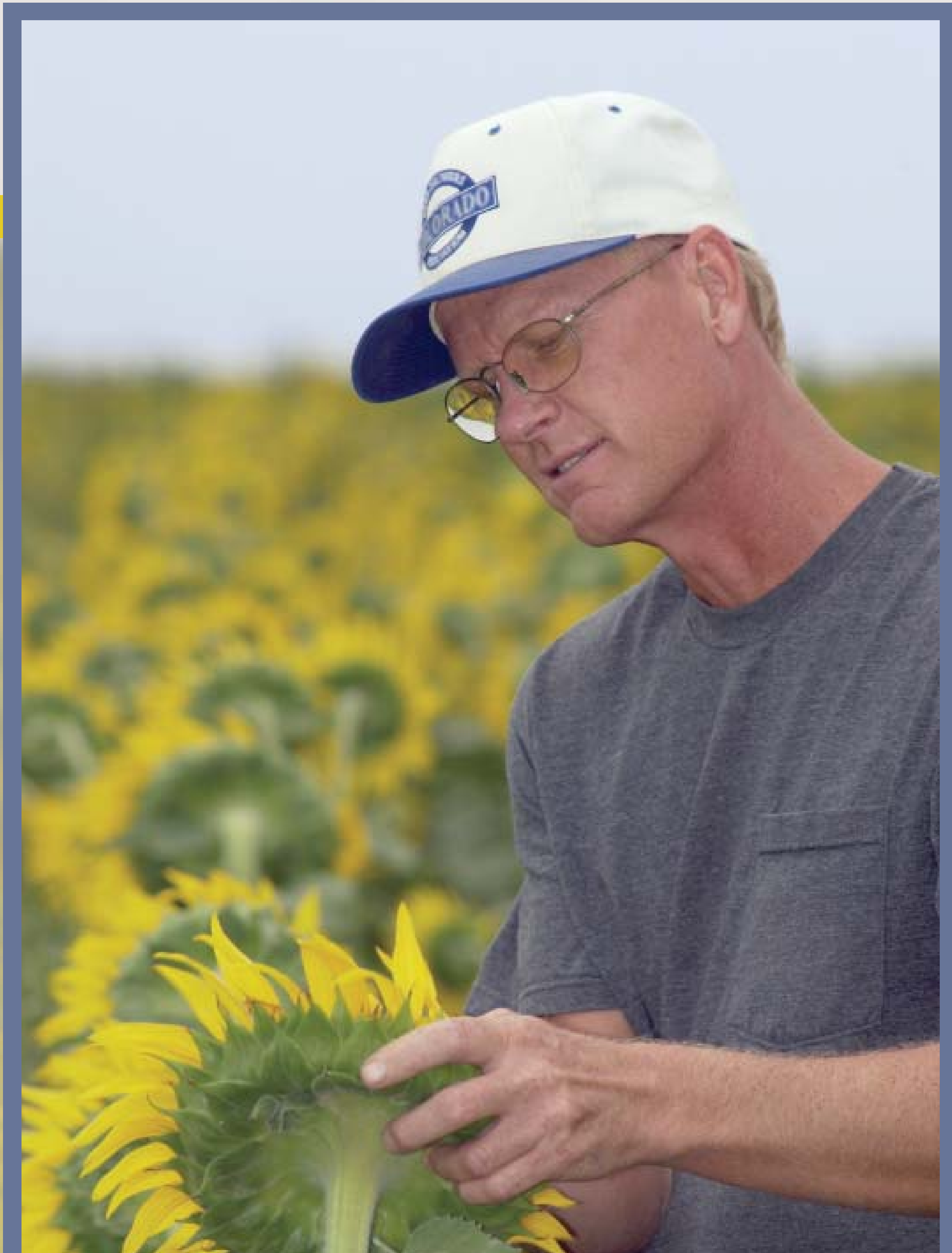
An additional benefit is that drip systems promote uniform yield. "Last year, my grain sorghum was as uniform as I have ever seen any crop," Larson says. "I have a yield monitor on my combine, and from one end of the field to the other, it didn't vary more than two bushels, whereas normally the yield could vary by 10 to 15 bushels. Yield uniformity suggests that a probable limiting factor, even water distribution, was overcome."

Typically, the advantage of drip irrigation is only economically viable for cash crops, such as vegetables, and is unaffordable for row crop farmers. However, the federal government is digging deep to help farmers go underground and make better use of water. A USDA aid program covers up to 75 percent of the cost of a subsurface drip irrigation system. "With this funding, it's cheaper to put in subsurface drip than to convert from furrow to center pivot irrigation system.," says Larson. The Plainsman Research Center system was purchased with funds from the Colorado Agricultural Experiment Station.

Subsurface drip irrigation isn't without its challenges, though. A good filtration system is a key component of a drip irrigation system. Any particulates in the water will clog the emitters, the small holes in the drip line. Draining the system for winter is important to prevent freezing. Larson also has had rodents gnawing at his drip line, causing leaks. Fortunately, leaks are easy to detect, locate, and repair.

This year's drought made subsurface irrigation unusually challenging for Larson. There wasn't enough moisture in the soil to germinate his seeds. The drip irrigation system isn't designed to reach all the way to the surface where the seeds are located. Larson was able to get his crops started since he still had the capacity to flood irrigate with gated pipe to get the crops started. In normal years, this wouldn't be necessary; however, in exceptionally dry years, some redundancy is in order.

The final hazard to subsurface drip irrigation is boredom, Larson jokes. "It's the most boring technology ever conceived. You can't even tell you're irrigating. I suppose if one of the trade-offs for high economic yield is boredom, then that's a small price to pay."



Friendly Secret Weapon

Spotted Knapweed Has Multiple Benefits

Scientists have speculated for decades that spotted knapweed is able to spread over large areas because of a secret weapon - an ability to release a chemical that kills surrounding plants. Until now, they have never been able to put their thumb on the phenomenon, but recently a Colorado State horticulture researcher who specializes in plant roots identified and isolated the chemical for the first time. What's more, the chemical is a completely natural and environmentally friendly herbicide that kills other weeds.

The discovery and isolation of the chemical, called catechin, within spotted knapweed may revolutionize the war against weeds.

"For years, scientists have talked about this chemical, but they couldn't find it because it was almost impossible to separate from all the other compounds that naturally occur in soil," said Jorge Vivanco, Agricultural Experiment Station researcher and assistant professor of horticultural biotechnology at Colorado State. "We looked for it in the plant and found that the roots secrete the chemical."

Vivanco and a team of researchers at Colorado State, including postdoctoral candidate Harsh Pal Bais and professor Frank Stermitz, are investigating a wealth of applications for the chemical.

Catechin, which can be extracted in laboratories, acts as a natural herbicide to most other plants, although grasses and grassy-like plants, such as wheat, show some resistance to it. This discovery alone holds much potential. For example, it may mean that specific amounts of catechin could be used on lawns to kill weeds without killing grass or on wheat without damaging the crop. The chemical also is environmentally friendly and has existed in the soil for decades.

Catechin kills other species of knapweed and is fatal to spotted knapweed only when artificially inserted into its cells in a laboratory. In nature, spotted knapweed does not permit catechin to re-enter the plant once the chemical is produced and released into the soil.

"It is a clever root to produce, secrete, and protect itself from this chemical," Vivanco said. "There are only small amounts of catechin inside the root at any given time; it secretes it as it produces it."

The team has found that spraying catechin on plants or adding it to soil is as effective as 2, 4-D against pigweed, lambs quarters, and other common weeds. Catechin usually kills cells within the plants in an hour and kills the plants in about a week. The team still is investigating the length of time that it remains active in the soil to prohibit plant growth and how far into the soil the chemical travels after it is released. They also are looking at counter-active chemicals that may be released by other plants, such as plants native to Europe and Eastern Europe, where spotted knapweed originated; many plants native to that area are resistant to catechin.

The researchers are working with commercial companies to make spotted knapweed catechin spray available to consumers within a year or two.

Colorado State researchers also are working to transfer the genes that produce the natural chemical into other plants to give them a built-in defense mechanism against weeds.

Perhaps one of the most promising applications of the discovery is the fact that spotted knapweed has such a complex defense mechanism. Spotted knapweed continuously secretes catechin, but immediately begins to produce and release higher quantities of chemicals at the slightest hint of a threat or stress. Just tapping its leaves automatically accelerates the plant's chemical response. This trait could impact how long it takes the soil to recover from the chemical to allow other plants to grow; for example, during stress, such as a drought or an infestation of insects that feed on the plant, more of the chemical may be released and over a longer period of time.

A Combined Effort

Precision Agriculture Takes a Closer Look

Seven researchers and a farmer stand in the middle of a cornfield one hot August afternoon on a farm near Brush. Each of them sees something a little different. One grabs a leaf and begins inspecting it, while another peels back the husk of an ear of corn. Others open the control panel on the sprinkler system and look inside. Some poke around at the soil. This group of more than 30 Colorado State University and USDA Agricultural Research Service scientists are part of an interdisciplinary team the Colorado Agricultural Experiment Station has assembled to find out how the latest technology can be used to farmers' advantage.

Farmers have always known that various parts of a field produce different crop yields. Regardless of the variability, they really had no choice but to treat an entire field the same with respect to applying fertilizer, water, herbicides, and pesticides. "A farmer may see an area that is beginning to wilt," says Dwayne Westfall, a Colorado State soil and crop scientist. "It may just be a sandy area, but he will irrigate the whole field with more water than is needed on most of the field, when in fact, he should reduce the application depth to what can be held by the sandy soil." However, that management strategy may be changing with the advent of precision agriculture–tools and techniques such as global positioning systems, geographic information systems, remote- sensing technology, yield monitors, grid soil sampling techniques, computer models, and variable rate applicators.

These precision farming technologies are being promoted as the solution to crop yield variability. "The problem is the industry is way ahead of the science," says Dale Heermann with the ARS, Water Management Unit.

There hasn't been enough research done to tell what the real issues are that result in yield variability.

But this multidisciplinary team of Colorado State scientists, extension agents, ARS Water Management Unit scientists, graduate students, industry partners, and cooperating farmers all are studying the same fields and comparing data to understand the causes of yield variability and see if precision agriculture offers economical and environmentally beneficial solutions.

"Our study in Colorado is unique," says Raj Khosla, precision agriculture specialist at Colorado State. "We take a systems approach in the use of precision technologies to make better decisions." The concept of this technology is not just the use of high-tech, precision agriculture tools, but rather the economical use of those tools that also results in environmentally friendly farming systems.

The scale of the project and the close collaboration of ARS and Colorado State scientists on the project are unique as well. All of the researchers are applying their expertise to actual farm fields. "The Colorado Agricultural Experiment Station funding has allowed us to move some of our research projects from a small scale, 20 by 30 feet in size, to fields as large as an entire 175-acre center pivot field," says Philip Westra a Colorado State Weed Scientist. "The scale is at a much higher level than what we typically use as individual researchers." Farmers appreciate this approach since it makes the research more valid in their real-world situation.

"Most research is single-discipline oriented," says Heermann. "We scientists tend to learn more and more about less and less. By working together, we bring our combined expertise to bear on experimental design and analysis, and we reduce the risk of tunnel vision." The precision agriculture team members also get the benefit of combining several scientists' worth of data into their work. "Every year, we learn something new," says Westfall. "That's what research is all about."

The researchers are using the advanced technologies and research methods in addition to farmers' experiences with their fields to determine what is really going on and what can be done to fix it. "This project is looking at the integration of all of the management factors and identifying how they affect the final yield," says Westra. "Yield is what the farmer is most interested in, so we're using new precision farming tools to create data layers for weeds, diseases, insects' fertility, irrigation, and other variables to figure out how they overlap and combine to affect yield in various parts of the field."

The geographic information systems, concept of data layers makes it possible to see where the factors a farmer has to deal with overlap and interrelate. A key element of the study is to determine the unit of variability that is reasonable for a farmer to manage. Early use of precision agriculture relied on intensive grid sampling. This approach proved to be too costly, particularly on crops with limited cash flow. Using remote sensing, the farmer's production experience, and statistical methods used in natural resource applications, the team has moved to a concept of production-level management zones.

By correlating data layers the team divides a field into management zones based on crop productivity: high, medium, and low, for example. The farmer's insight is an important component."We are cognizant that the farmer knows which parts of his field are high production and which are low," says Westfall. "We are trying to integrate all of our information together, with heavy reliance on the farmer's experience."

The theory is that when management decisions are based on productivity zones, a farmer can make the most economical use of techniques of applying water, nutrients, herbicides, pesticides, and other inputs. In the past, a farmer may have been tempted to spend significant amounts of money on an entire field including parts of a field that were not going to be productive, no matter what.

Using precision farming techniques, a farmer can identify parts of the field that need special attention. The farmer can then decide if an input will be cost-effective, given what the zone will ultimately produce.

The multidisciplinary approach fostered by the Colorado Agricultural Experiment Station and the Agricultural Research Service is the key to both creating the data layers and evaluating their relationships. For example, the researchers are finding relationships between soil type, fertility, and weed and insect infestation. A major component of this project is determining what drives these overlapping field relationships.

Weed scientists like Westra are looking at the spatial distribution of weeds and how they can be combated. At the same time, ARS scientists led by Heermann are evaluating technologies such as AccuPulse for delivering fungicides with irrigation systems. This system is unique in that it uses the existing center pivot to get around the field, but its delivery system is independent of irrigation piping, unlike chemigation systems. Therefore, the chemical is prevented from flowing back into the well, and a higher concentration of product can be applied since it is not diluted with irrigation water; and it can be applied exactly where needed. The ARS scientists also are researching the use of soil electrical conductivity technology for mapping soil types and the use of remote sensing to determine the crop's nitrogen status.

Plant pathologist Howard Schwartz is studying the spatial characteristics of plant diseases and testing treatments for the diseases. Colorado State entomologist Frank Peairs is providing data on insect activity. He and a staff of research associates and graduate students monitor traps for such pests as European corn borer, western bean cutworm, and western corn rootworm. Khosla and Westfall are working on managing nutrients. They use high-tech approaches such as monitoring chlorophyll content and leaf area spatial variation to evaluate the effectiveness of nutrient application.

Tim Green with the ARS is studying the advantages of variable-rate seed planting for dryland systems. Weather data at the research fields, including solar radiation, temperature, wind run, vapor pressure, and precipitation, are collected and correlated. Precision agriculture project manager Kim Fleming; Raj Khosla, precision agriculture state specialist; and Cooperative Extension Agent Bruce Bosley are working to get farmers involved and transfer the results of the project to them.

Evaluating the economics of precision farming is a necessary component of the project. "If a farmer cannot make money with precision agriculture, he's not going to adopt it," says Westfall. However, what may not be economically feasible today may become a necessity in the future. Farmers can see the day coming when they may be legislated into using only a certain quantity of nutrients, herbicides, or pesticides on their farms. It will be up to the farmer to figure out where and when to best apply them.

Precision agriculture may make a huge difference in both the decision and the application. "The only thing that hasn't gone up triple or quadruple in the last 20 years is the price of corn," says Larry Rothe, a cooperating farmer from Wiggins. "Our only chance is to figure out how to do it with less money."

An additional commitment to precision agriculture by Colorado State is the creation of a new degree concentration: Applied Information Technology in Agriculture in the Department of Soil and Crop Sciences. Undergraduates are trained in both technology and agriculture in this unique program.

"I think precision agriculture is the wave of the future," says Westfall "We just don't know what it will end up looking like in another 10 years. It may be something we can't even envision today, but it is here to stay."

Question Predictions

Research Turns Focus to Long-Term Climate Effects

On the wall in Roger Pielke's office is a bumper sticker that provides a clue to the state climatologist's way of thinking: "Question Predictions."

It's not that Pielke, who also is a professor in the Department of Atmospheric Science and president of the American Association of State Climatologists, doesn't believe in predictions. But to help people affected by the weather – and that includes just about everybody – Pielke would like to see the emphasis shift to vulnerability and resiliency rather than concentrate on predictions.

In fact, Pielke gave testimony to that effect to the House Committee on Energy and Commerce in Washington, D.C., in late July.

"The House testimony provided both my perspective and the perspective of the AASC that there really is no foolproof method known to science to predict long-term climate because of the many feedbacks between land surfaces, the atmosphere, oceans, and other variables," Pielke says. "As well, the human influence on climate is significant and multifaceted and has greater impact on climate than what has been suggested by national and international assessments."

"By focusing on vulnerabilities rather than predictions as a focus of research, I think the scientific community can provide more comprehensive and likely more useful information to decision makers."

As an example, Pielke says that tree-ring records over the past 800 years show more serious droughts than those experienced in the 20th century, and those events were natural – humans had little or no influence. He suggests that our society needs to plan ways to deal with events on the magnitude of such climate changes, especially in light of the burgeoning human population and higher demands on resources now taking place.

Pielke's taken a big step in that direction with the establishment of DroughtLab with colleagues Jose Salas, professor of civil engineering, and Robert Ward, director of the University's Water Center and the Colorado Water Resources Research Institute. DroughtLab is a new collaborative drought analysis and management laboratory that redirects current resources and establishes new studies to provide information to government leaders, businesses, and individuals as they plan for and manage drought events. Along with Pielke, Salas serves as co-director of the lab.

The lab brings together the knowledge of more than 100 researchers from 22 academic departments at Colorado State and labs and departments at the University of Colorado at Boulder. Disciplines contributing to DroughtLab's efforts include atmospheric science, civil engineering, watershed sciences, soil and crop sciences, rangeland science, forest science, ecology, sociology, political science, and agricultural and resource economics.

"Severe Colorado droughts, such as the one we currently are experiencing, have occurred in the past and will happen again in the future," Pielke says. "With increased population along the Front Range, our vulnerability to severe drought has greatly increased."

DroughtLab serves as a framework for researchers to collaborate and develop a wealth of information that helps water managers reduce Colorado's vulnerability to drought. Research will be conducted on campus and across the state at the Agricultural Experiment Station research centers located in communities throughout Colorado. Outreach education, statewide Cooperative Extension efforts, technology transfer, and the communication of drought knowledge to state and local officials and the general public will complement the lab's research efforts.

While Colorado is quite vulnerable to drought, Pielke says that vulnerability varies with specific water users.

"For agricultural interests on the eastern plains, wet fall seasons would be great – the dryland farmers could actually recover fairly quickly from dry summers. But the municipal water supplies of the Front Range cities require longer recharge time, and that's one reason why the DroughtLab will look at these diverse impacts to try to quantify them so managers know what we can recover quickly from, what takes longer, and what they can do to help mitigate or adapt to droughts."

In the end, Pielke recognizes the difficulty in understanding all the variabilities of climate and how land-use alters the local microclimate and cumulatively affects the regional climate, but that's not going to keep him from asking "what-if" questions: If we had an above-average rainfall, could we recharge the aquifers, given what we know about the system? What would happen to our reservoirs if we have a dry winter? How vulnerable are we to long-term drought?

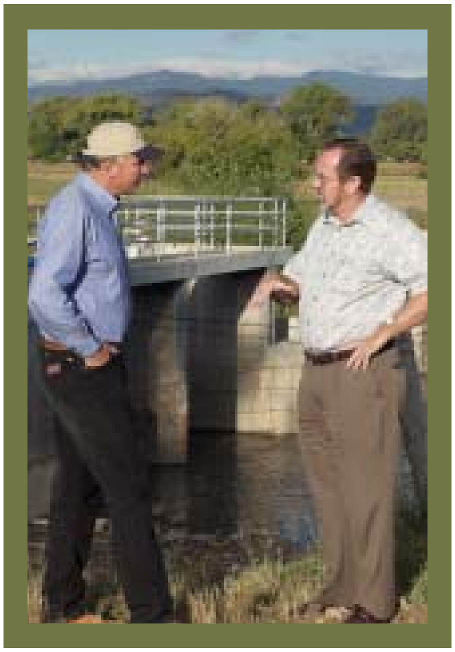
And those are some big questions that keep Roger Pielke coming back to work every day. "Climate is multidimensional, unpredictable, and fascinating," he says.

The Water Traders

100-Year-Old Exchanges Along the Cache la Poudre

In dry years like the West has experienced recently, it's not hard to understand why water has always been a source of power and struggle among the haves and have-nots. When Colorado was still wild, many water disputes were settled with gunfights and fist fights; today, water is as precious a commodity as ever, and its management is sometimes still a source of contention.

About 100 years ago, residents and water managers along the Cache la Poudre River began the practice of trading water as a peaceful way to manage the river so the needs of all residents were met equitably and with mutual benefit. For example, when an upstream owner needed more water in the spring than the fall while a downstream owner needed more water in the fall than the spring, the two groups traded water. Today, the practice of water exchanges continues, but water management and water resources to serve ever more diverse needs and people who may not understand and value the old system are becoming strained.



In a recent study, John Wilkins-Wells, a senior research scientist in the Department of Sociology, and several colleagues found that not only does the long-trusted system of water exchanges still work and work fairly well, but the system also continues to illustrate how managers can cooperate inexpensively to share scarce resources.

"Water exchanges play an important role in the Poudre River Basin because they accommodate different needs in the upper and lower basin, different junior and senior water right holders, and differences in water availability," says Wilkins-Wells. "Water exchanges are a socially important strategy in meeting demands and reducing conflict over water because they require communities to work cooperatively in managing their water resources. Water exchanges are inexpensive and don't require a lot of infrastructure; in fact, they often decrease the need for new storage facilities because they allow water to be moved around the basin to address specific needs in a flexible system."

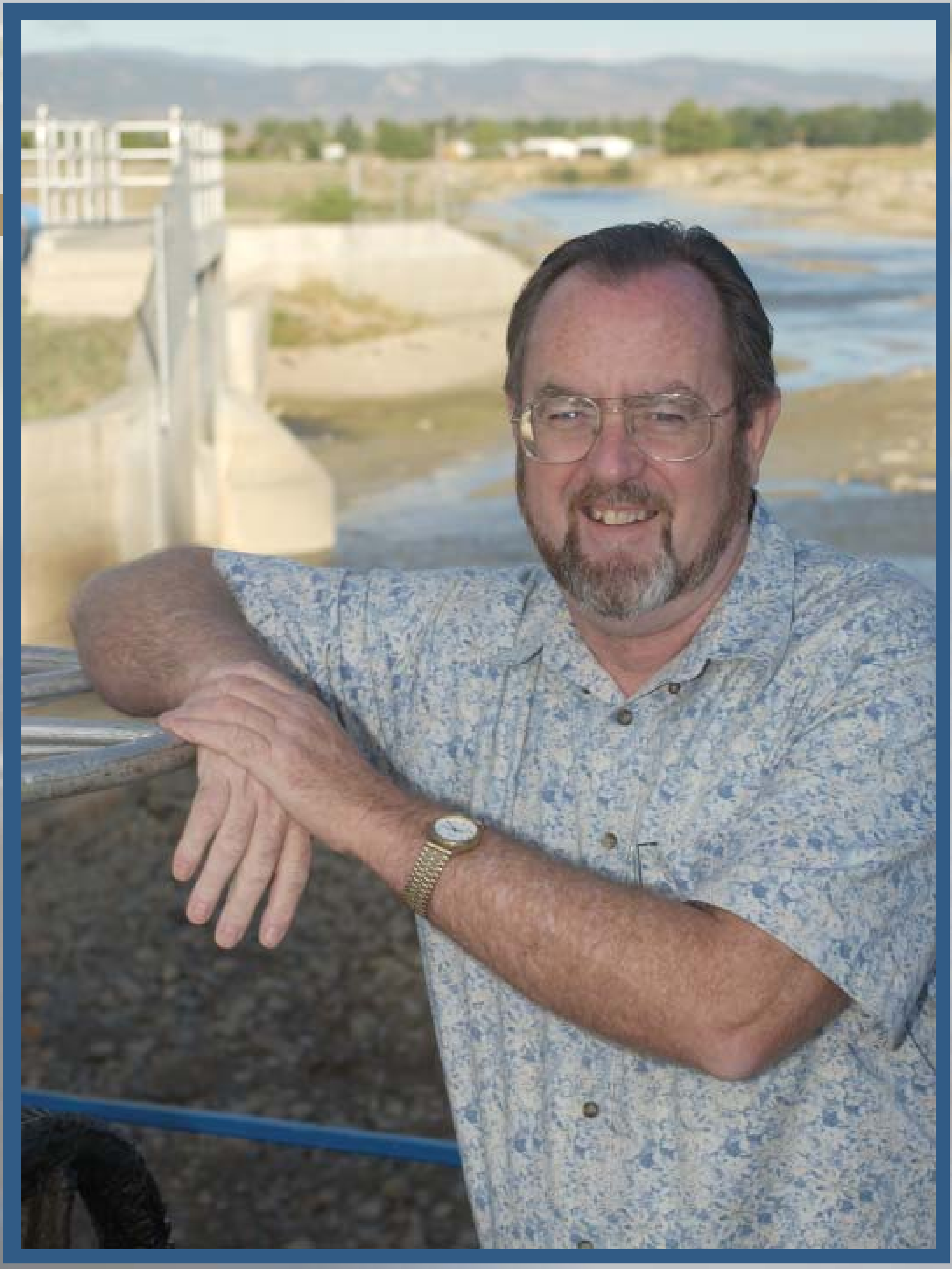
In recent years, the use of water exchanges has caused conflict as water is reallocated to fill urban needs. Water exchanges can be viewed as a nuisance by municipalities and recreational interests. With increased pressure from urban use, water exchanges also are frequently harder to perform because there is less water that isn't being used.

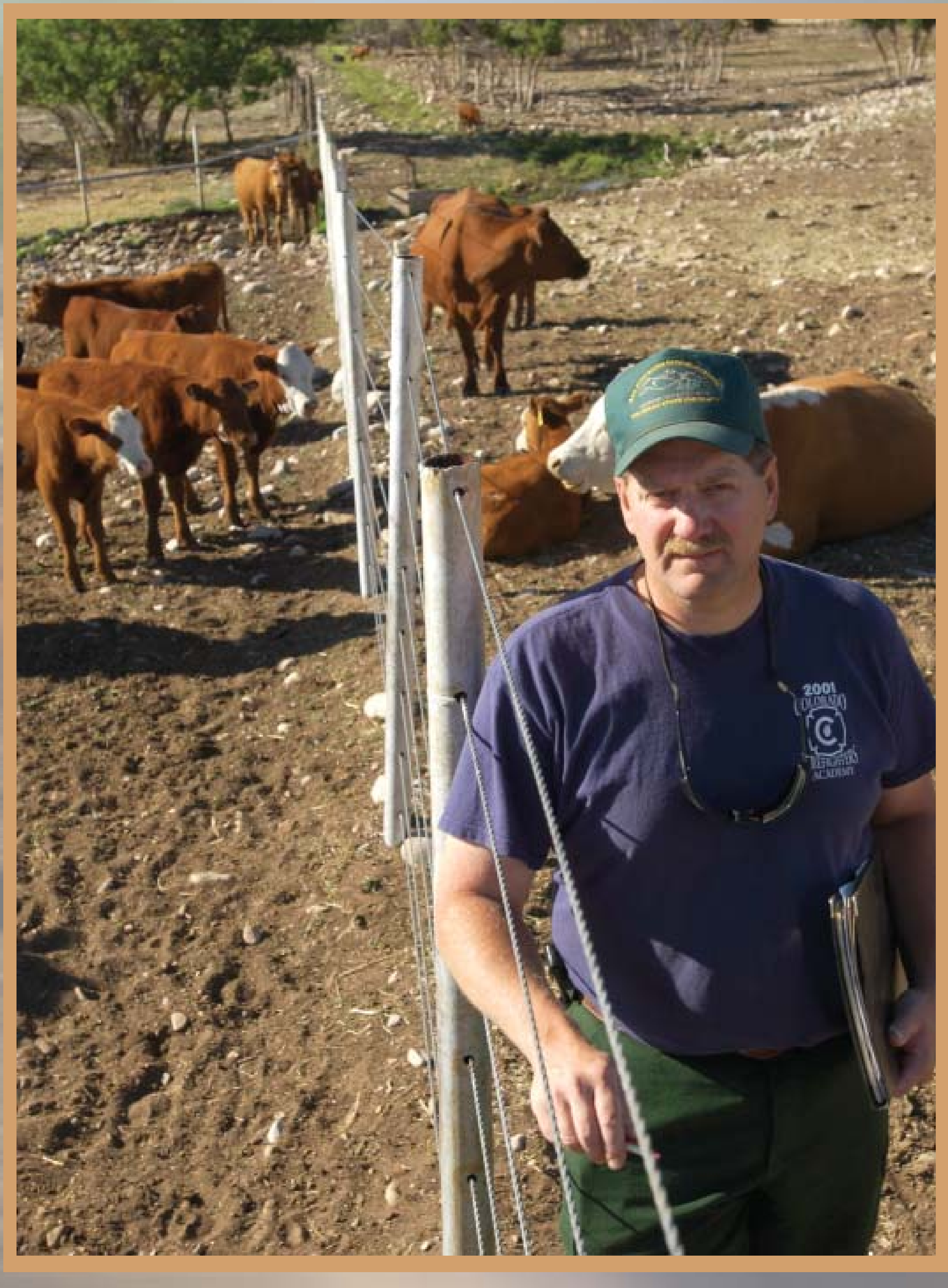
Many water users in the Poudre Valley feel that if the water exchanges are discontinued because of new demands, agricultural production in the valley will decrease. Agriculture is important to the area economically and aesthetically by providing wildlife habitat and open space. Water exchanges allow landowners to water crops and pastures later in the season than normal stream flow would allow, meeting the modest but important differences in the upper-and lower-basin growing seasons.

"The big downside is the potential disruption to important water exchanges that meet crop production needs and maintain a balance in canal flows. These exchanges often are forgone because a cooperating exchange partner no longer can be found due to changing philosophies," says Wilkins-Wells. "Irrigated lands in the Rocky Mountain region are unique, producing crops that represent an important, irreplaceable sector of national food production. For instance, the removal of production through urbanization tends to directly affect farmers who raise specialty crops, vegetables, fruits, berries, sugar beets, beans, potatoes, and barley that consumers enjoy as fresh, local produce and important feed crops for the red meat and dairy industry."

Wilkins-Wells points out that new management options - such as water markets, water rentals, interruptible water supplies, water banks, expanded water reuse capabilities, and pressurized secondary supply systems - are in part expansions of water exchanges.

"Water exchanges play a role in all of these new approaches to water management. They are the lubricant for other practices," says Wilkins-Wells. "If water exchanges are lost or disrupted due to a misunderstanding about their function or importance, then the entire river basin management program begins to unravel. Whether or not they are central to river basin management today may be questioned, but they are certainly an essential component of this management."

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Head Start for Calves

Late Season Calving Improves Costs and Profits

On a blue-sky day at the foot of the LaPlata Mountains, Douglas Zalesky, superintendent of the San Juan Basin Research Center walks among one of his two herds of cattle. The calves are small for late August, but they're supposed to be. The calves are part of a five-year experiment to test the efficacy of late-season calving at the San Juan Basin Research Center near Hesperus. The study is an example of how the research center is conducting management research to mimic a commercial ranch. "We are doing more systems-type research to study how resources intertwine," says Zalesky.

Traditionally, cows are bred to calve during March and April to get steers ready for market as early in the year as possible. "March and April is about as early in the spring as ranchers can get away with," according to Zalesky. However, calving so early in the spring may come with a price of increased feed, labor, machinery, and health costs.

Zalesky theorizes a later calving season in May and June will offer ranchers some economic gains. A cow's nutrient requirements are highest right after calving. Little forage is available during the traditional March and April calving season, so ranchers must feed their herd hay and alfalfa. By May and June, natural forage availability and its nutrient content are much better. The herd's feed may need to be augmented in the fall, but the herd's nutrient demands are lower at that stage of development than in the spring. The later calving season may be a better match between cow nutrient requirements and forage nutrient production. This should reduce the costs of feed and the labor of getting the feed to the herd.

In addition, similar studies done in Nebraska have indicated a lower incidence of calf illness and fewer deaths associated with a later calving season. The ultimate market price for steers may be better with late-season calving as well. "By selling later, there can be an advantage as prices rebound after the flood in the market in October and November," says Zalesky.

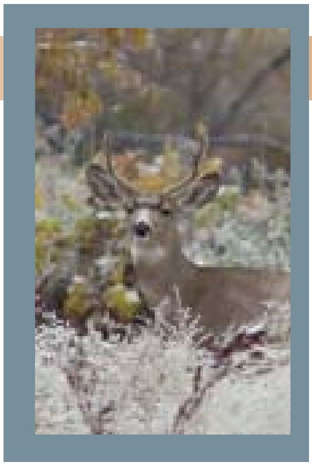
To test the theory, Zalesky randomly divided in two a herd of cattle at the San Juan Basin Research Center in May 2001. One herd was bred to calve in the traditional March/April season and the other in May/June. Over five years, the herds will stay separated and repeatedly bred for their corresponding calving season. The calves from both groups will be weaned at seven months. Heifers born to each herd will remain as replacements.

Zalesky will record and analyze statistics on breeding, calving, weaning, and health. He will track nutrient content of the forage and the amount of hay produced at the research center and its nutrient content. Economic variables including the amount of hay fed, and its cost, labor costs, health costs, and net values of calves will be evaluated. So far in 2002, Zalesky has had to feed approximately one-third less hay to the late calving group as compared to the traditional herd.

The drought is setting back the study because of the lack of natural forage. At the research center's 7,500-foot elevation, there are only about 100 days to grow feed. Zalesky thinks the later calving season will optimize this short growing season typical of the Four Corners region. Since the San Juan Basin Research Center's study is similar to a commercial ranch, the results of the study will be readily applicable to the region's ranches.

Chronic Wasting Disease

New Prion Research



When Ed Hoover became interested in chronic wasting disease, little was known about the mysterious illness or what caused it. CWD is a transmissible neurological disease of deer and elk characterized by loss of body condition, odd behavior, and death.

Despite the mystery, Hoover at first was reluctant to get involved in CWD research. His work in the Department of Microbiology, Immunology, and Pathology at Colorado State focused on viruses–his research developing a vaccine against the feline leukemia virus has resulted in the near eradication of that once highly prevalent disease. But the infectious agent of CWD is neither virus nor bacteria. It appears instead to be a prion, essentially a protein without associated nucleic acids.

The discovery that proteins alone can transmit an infectious disease came as a considerable surprise to the scientific community.

One of the darkest puzzles of prion diseases is the possibility of their crossing from one species to another. Several mammalian species develop prion diseases including sheep, which develop scrapie, and cows, which develop bovine spongiform encephalopathy or mad cow disease. There is also a human form, Creutzfeldt-Jakob disease.

In England during the mid-1990s, an outbreak of mad cow disease was caused by the feeding of sheep parts to cattle. The sheep were infected with scrapie. The cattle developed mad cow by eating the infected sheep. Then people developed a form of Creutzfeldt-Jakob disease by eating the infected beef.

While the possibility of human infection from CWD is of great concern, it is important to note there have been no verified cases linking CWD to human Creutzfeldt-Jakob disease, Hoover says.

Nonetheless, after the mad cow disease outbreak, the Colorado cattle industry took notice of prion diseases like CWD. And when Hoover overcame his initial reluctance to study CWD, he found a ready ally in the Agricultural Experiment Station.

The Agricultural Experiment Station provided Hoover seed money through Colorado State's College of Veterinary Medicine and Biomedical Sciences to begin studies on the oral transmission of CWD. At the time, there was no study of the potential route of transmission of CWD, Hoover says.

"We began with a study to determine if CWD was transmitted orally. We found that it was in the tonsils and lymph nodes long before it reached the brain. We demonstrated that CWD can be transmitted through oral exposure," Hoover says.

The success of that initial study encouraged other funding agencies to invest in Hoover's work, leading to further investigations.

"We've gone on to study the nerves as the agent's transit route to the brain. We did some studies on the location of the agent in lymphoid tissue to give us some clue as to how it got there and whether the lymphoid system, which is part of the immune system, actually is participating in the evolution of the disease, because it is thought that there's no immune response in prion infections.

"We've also tried a new approach of inoculating deer with prions–an approach that is being pioneered in the study of Alzheimer's disease in humans," he says.

Earlier this year, the National Institutes of Health awarded a seven year, $8.4 million grant to a research team led by Hoover to study CWD in deer.

The goals of the project are to:

- determine through bioassay in deer whether the infectious agent is contained in blood and other body fluids;
- determine whether CWD is transmissible to other species;
- develop transgenic mice susceptible to CWD, which would make the study of the disease infinitely easier and less costly than studying it in deer (this work is being done by Dr. Glen Telling at the University of Kentucky); and
- develop and test vaccine approaches for CWD.

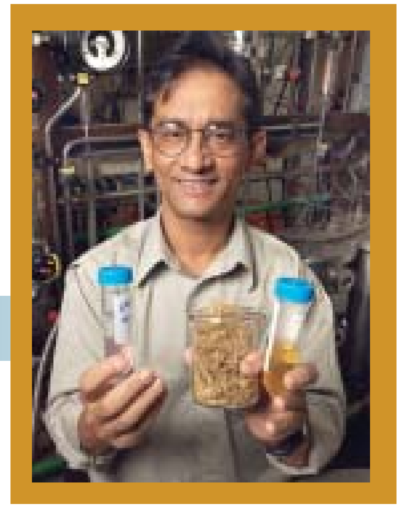
To house these studies, Hoover wants to raise additional support to build a biosecure deer housing facility in which to safely study the disease under controlled conditions.

For all the mysteries surrounding CWD, one thing is clear: The threat is real and immediate. Consider that deer and elk hunting pumped $599 million into Colorado's economy last year according to the Colorado Division of Wildlife. There's no mystery about the impact to the state if hunters quit hunting in Colorado for fear of contracting CWD.

"As far as the maximum impact of CWD, I don't think anyone knows yet," says Hoover.

Waste Not, Want Not

"Value-Added Process" Produces Ethanol from Crop Waste



If you want to get more for your money, all you have to do is waste less. Nazmul Karim, Linda Henk, and other researchers at Colorado State University are applying this simple maxim to make agricultural crops more valuable, produce cleaner-burning alternative fuels, and reduce agricultural waste, all at the same time.

"Our work for the Agricultural Experiment Station is to devise processes that make use of the parts of agricultural crops that normally are thrown away," Karim says.

Karim, a professor; and Henk, a research scientist and microbiologist; in the Department of Chemical Engineering; James Linden, a professor in the Department of Microbiology, Pathology, and Immunology; and others are working on a process for producing ethanol from lignocellulosic material in agricultural waste.

"All plants, grass, trees, you name it–all the parts that aren't used for food and other products are of lignocellulosic material, which can be utilized for a higher value other than burning or destroying or letting it rot," says Karim.

Lignocellulosic material is a combination of cellulose, a complex carbohydrate that forms the main constituent of the cell wall in most plants, hemicellulose, and lignin. Lignin is a polymer that strengthens plant tissue by binding cellulose fibers. For most agricultural products, these materials are regarded as waste.

Current processes for producing ethanol use corn kernels, which makes ethanol production more expensive because corn kernels have value as a food product. Using lignocellulosic material would reduce the manufacturing cost of ethanol but only if the challenge of deriving sugars from this material is first overcome, says Karim.

Ethanol production consists of acid hydrolysis pretreatment of plant matter to break the polymers and derive sugars that can be fermented to make ethanol. Karim's team is investigating two acids–sulfuric and phosphoric acids–for pretreatment on ligno-cellulosic materials.

"Sulfuric acid does a good job deriving sugar that can be fermented into ethanol, but there are other difficulties," Karim says. Sulfuric acid leaves residue and compounds that are detrimental to the fermentation process, requiring additional purification steps.

The team also is investigating phosphoric acid pretreatment.

"Phosphoric acid pretreatment produces a little less sugar than sulfuric acid, but it does not produce some of the harmful by-products, or it produces them at greatly reduced levels. And phosphoric acid pretreatment produces phosphates, which are a beneficial by-product because they are required by microorganisms used in fermentation."

The pretreatment breaks down lignocellulosic material into xylose (a sugar), cellulose, and lignin. The cellulose is converted to glucose (also a sugar) through treatment with enzymes. Henk is investigating the use of cellulase enzymes for that purpose.

"The pretreatment breaks apart the woody structure so the cellulase enzymes can access the cellulose," Henk says. "The enzymes actually break apart the cellulose molecules, which are chains of sugars hooked together."

The sugars are destined for fermentation into ethanol. The lignin can be used as a medium for growing mushrooms–another value added by the process. A final obstacle is that xylose, a five-carbon sugar, is not as readily fermented into ethanol as glucose, a six carbon sugar. To clear this hurdle, the researchers turned to the National Renewable Energy Laboratory (a DOE facility) at Golden, Colo., that has developed a genetically modified microorganism, *Zymomonas mobilis*, which can break down both glucose and xylose.

"Right now, we are comparing the different methodologies to find the most efficient process," says Karim.

Karim acknowledges there are obstacles to widespread adoption of ethanol. In Colorado, oxygenated fuel with 10 percent ethanol is sold at gasoline stations, because it produces less pollution, but ethanol production currently is subsidized by the federal government because of the cost.

"Gasoline is kept at an artificially low price in this country, which makes this technology seem expensive," Karim says. "But if Americans were forced to pay the prices consumers elsewhere in the world do, it becomes more feasible."

Either way, Karim, Henk, and the others are determined to make the process work because it makes sense on so many levels.

"We've worked on this process since the late 1970s during the Carter administration," Henk says. "It will reduce our dependency on foreign oil, it will reduce carbon emissions from fossil fuels, and it will help the agricultural economy in rural America."

Colorado Agricultural Experiment Station Contributors

Colorado State University Colleges and Departments

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Department of Agricultural and Resource Economics
Department of Animal Sciences
Department of Bioagricultural Sciences and Pest Management
Department of Horticulture and Landscape Architecture
Department of Soil and Crop Sciences

College of Applied Human Sciences

Department of Design and Merchandising
Department of Food Science and Human Nutrition
Department of Health and Exercise Science
Department of Human Development and Family Studies

College of Engineering

Department of Atmospheric Science
Department of Chemical Engineering
Department of Civil Engineering

College of Liberal Arts

Department of Sociology

College of Natural Resources

Department of Forest Sciences
Department of Rangeland Ecosystem Science
Natural Resource Ecology Laboratory (NREL)

College of Natural Sciences

Department of Statistics

College of Veterinary Medicine and Biomedical Sciences

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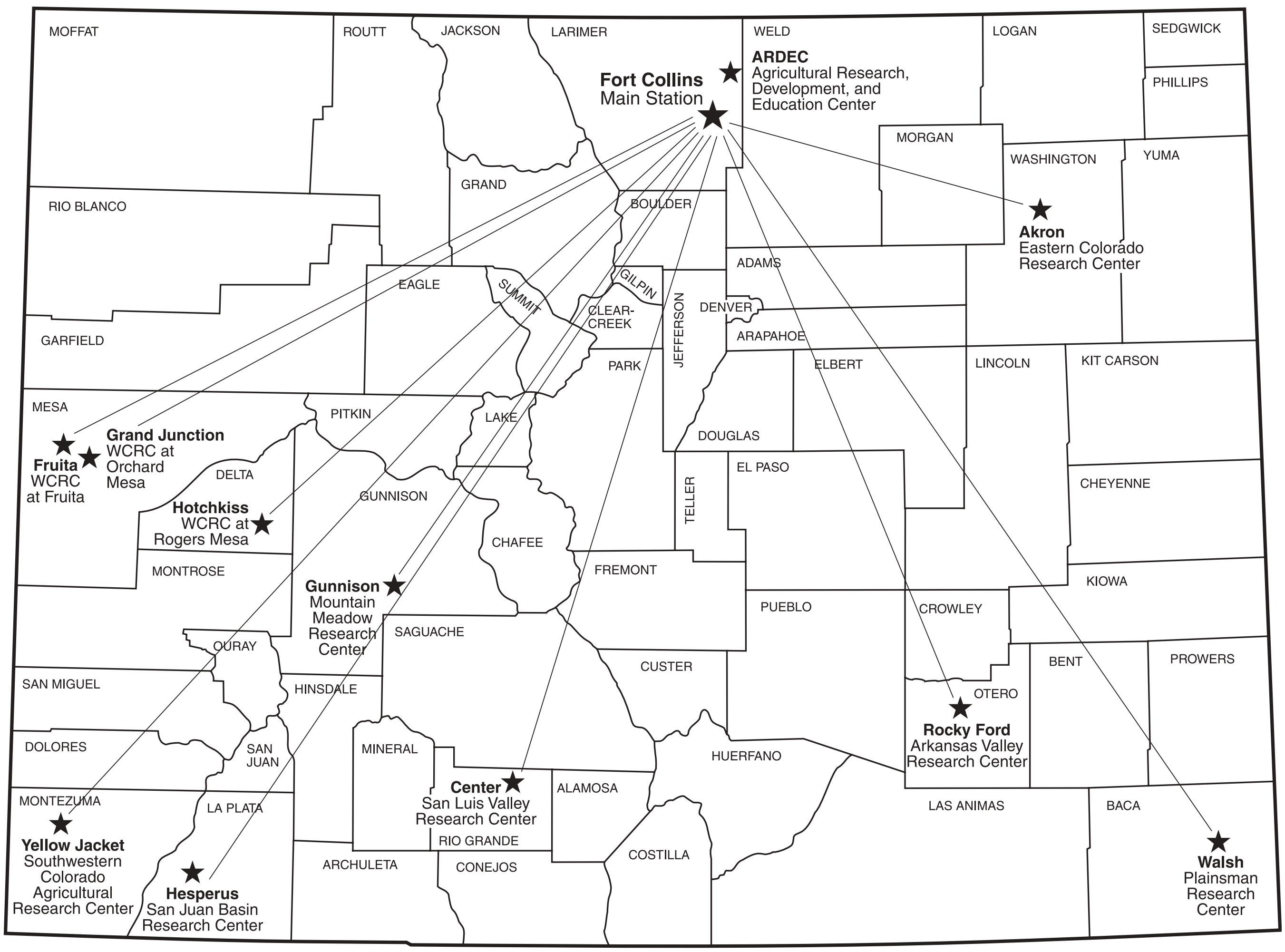
Colorado Agricultural Research System



Colorado Agricultural Experiment Station Funding for Fiscal Year 2002-2003

The Agricultural Experiment Station at Colorado State University is funded by appropriations from the Colorado legislature through the Colorado Commission on Higher Education, appropriations from the federal government through the United States Department of Agriculture, and from self-generated income through the sale of commodities. The relative amount of each funding source is shown in the chart.

• State – Funds appropriated by the Colorado legislature and allocated to Colorado State University by the Commission on Higher Education.

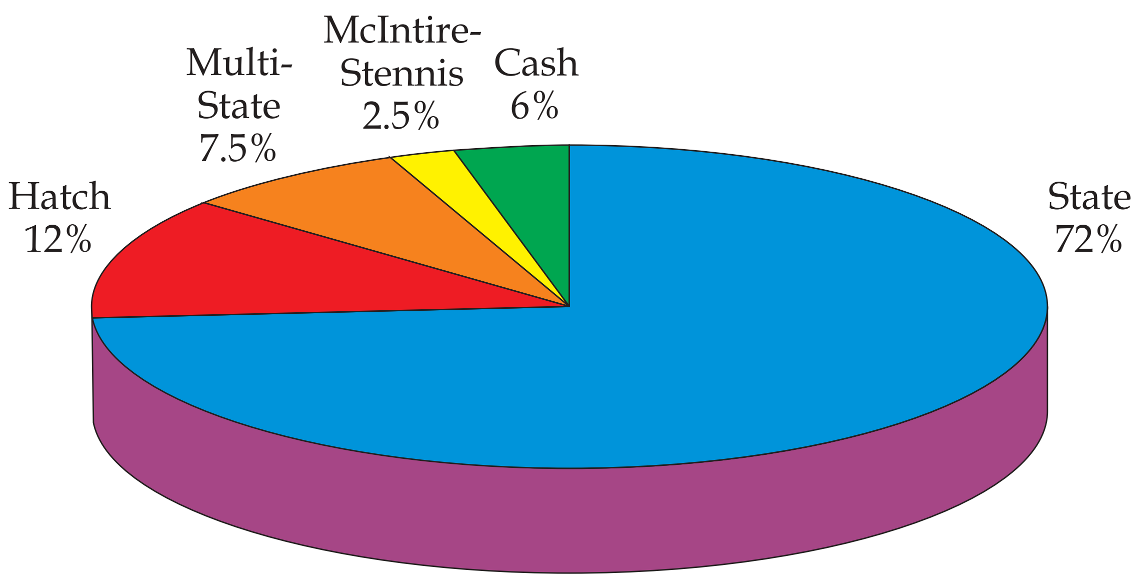
• Hatch – Funds appropriated by the federal government to each land-grant university for support of a base research program in agriculture and natural resources. These funds were authorized by the Hatch Act of 1887, as amended by the Agricultural Research, Education, and Extension Reform Act of 1998 and administered by the Cooperative States Research, Education, and Extension Service of the United States Department of Agriculture. The funds are prorated to each state based on a formula that includes several factors such as rural population and number of farms.

• Multi-State Research – A portion of the Hatch funds are mandated by Congress to be applied to research problems that are regional in nature and involve the efforts of several states. Funds are administered the same as Hatch funds.

• McIntire-Stennis – Funds appropriated by the federal government to support research in forestry and forest resources. Funds are administered the same as Hatch funds.

• Cash –Funds originating from the sale of goods and services associated with Agricultural Experiment Station programs. Commodities sold include crops and livestock, which are by-products of applied research programs conducted at research centers.

In addition to the above direct funding sources, scientists supported by the Agricultural Experiment Station are active in securing contract and grant funding from numerous private sources, as well as state and federal agencies. In the 2001-2002 fiscal year, contract and grant funding from these external sources contributed in excess of $20 million of support to our research programs.



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