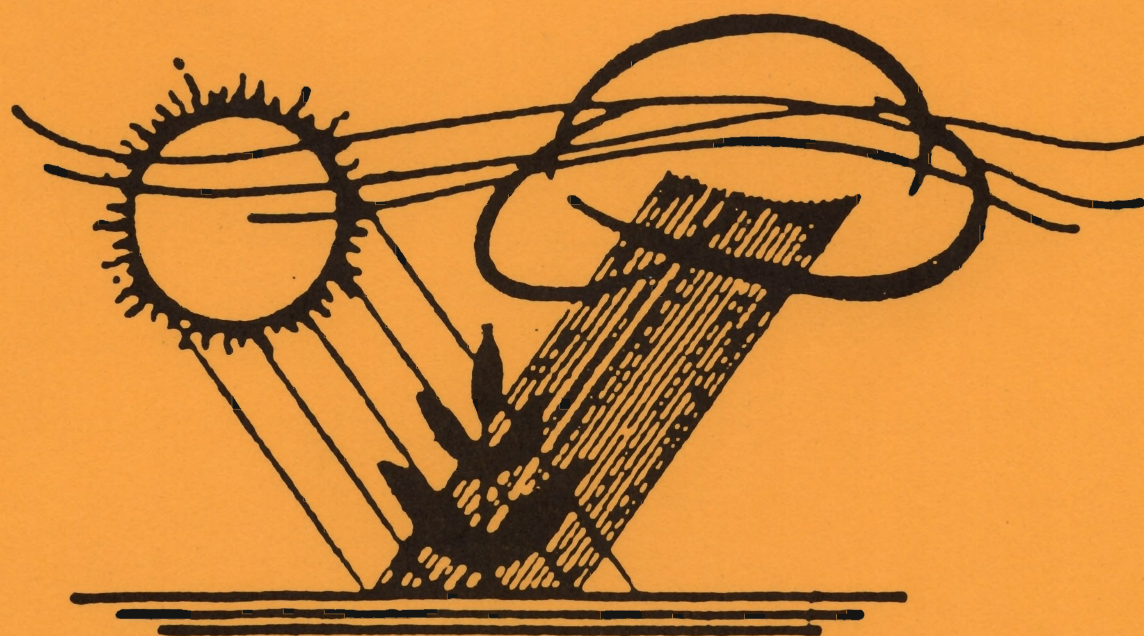
PROCEEDINGS
1994
CALIFORNIA PLANT
AND
SOIL CONFERENCE

PROACTIVE ROLES FOR AGRICULTURE



CALIFORNIA CHAPTER
AMERICAN SOCIETY OF AGRONOMY

CALIFORNIA FERTILIZER ASSOCIATION

January 24-25, 1994
Pacific Suites Hotel & Conference Center
San Luis Obispo, California

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Sponsored By

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FEDERAL AND STATE STRATEGIES TO KEEP

AGRICULTURE IN A PROACTIVE ROLE[1]

In order for agriculture to be viewed in a proactive role we must demonstrate the "value" of agriculture to the individual. Today's citizen is a couple of generations removed from production agriculture and has grown up having an abundance of food, both in amount and choice. Unlike in Europe, Japan and less developed nations, food security is not an issue, nor is the concept of agriculture's role in the economy and health of the nation. In fact the public perception of US agriculture as presented in the visual and print media is that agriculture is a major source of environmental damage by polluting surface and ground water, eroding soil, increasing PM-10, reducing biological diversity by monoculture and eliminating endangered species through the use of pesticides. According to the media, we also use excessive amounts of water, treat farm workers improperly, displace small family farms with "corporate" agriculture and are ripping off the tax payer by growing subsidized crops already in surplus. And if this were not enough, our food is no longer safe to eat and we want to use new technology, such as genetic engineering, which defies the laws of nature. So not only do we have to deal with a public which is not agriculturally or scientifically literate, but also with a public which believes we are a major part of the environmental problem, the food safety problem, and are costing them a lot of tax dollars.

What are the arguments that we can make to present the case that agriculture is a major contributor of value to society and that it is the solution to a number of societal problems both real and perceived, rather than the cause? The arguments must be presented in a way in which the average citizen can see a direct impact upon his or her needs. Therefore, the way in which the positive case is presented will vary from time to time depending upon what are the current concerns of the public. Right now the issues are the economy, diet, nutrition and health, food safety, the environment, and accountability for the use of taxpayer funds.

Let's review how California agriculture contributes to each of these issues. From an economic standpoint, agriculture is not only one of California's most important industries, but also, it, unlike the service industry, produces something of value. We are not just trading dollars back and forth; rather, agriculture creates new value which could not be more critical at this time in our state or nation's history. In the Central Valley farming and farm-related industries create nearly a third of all jobs, produce 27.2 percent of value-added dollars, and generate about $1 of every $3 of personal income. Direct and indirect sales from farming add $50.8 billion to the Central Valley economy. Even though total revenues dipped in 1991 because of the cumulative effect of six consecutive drought years and the 1990 freeze, exports rose to a record new high of $4.66 billion, 46.8 % going to the growing

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[1]Presented by Charles E. Hess, Director, International Programs, College of Agricultural and Environmental Sciences, University of California, Davis, CA 95616 at the California Plant and Soil Conference, California Chapter of the American Society of Agronomy and California Fertilizer Association, San Luis Obispo, CA, January 24, 1993.

Pacific Rim market. This is a significant contribution to the nation's balance of payments. California farmers out-produce every state in the nation, leading the nation for 44 consecutive years.[2]

California agriculture produces over half the nation's fresh fruit and vegetables. In terms of diet, nutrition and health, there is growing evidence that these high-value commodities contribute directly to the maintenance of good health and help prevent heart disease and cancer as well as being an important component of everyone's diet.

California produce is grown under strict regulatory controls by the California Environmental Protection Agency and the State Department of Food and Agriculture. California's ideal growing conditions with abundant sunshine and little or no rainfall during the production season, reduces dependency upon pest controls. California produce is among the safest in the world.

California agriculture maintains open space and helps keep California green. Agriculture can enhance both the physical and the aesthetic environment. Farm land converted to housing, roads, and industry, leads to increased pollution which threatens the quality of life in the Central Valley and other areas of California.

Other arguments, beyond today's major concerns that could be used for the positive contributions of agriculture, include food security, the recognition that agriculture is one of the nation's great social benefit programs, and that it can help address global environmental concerns.

Although our nation has not experienced food shortages, people do remember fuel shortages. The dependency upon foreign fuel has made the US very vulnerable and has led foreign policy and the investment of US lives in activities such as the Gulf War. We should not permit the US to become dependent upon other nations for our food in general, and in particular, the fruits and vegetables that California produces so well.

A second point along this issue is the fact that the world's population is currently growing at a rate that results in a doubling of population every 42 years. The Consultative Group on International Agricultural Research has stated that in the next decade, we will have to increase food production by 40 percent in order just to maintain current caloric intake. This will have to be done in a declining area of cultivated land and in a way that is environmentally sensitive. While it is true that there are current surpluses and that part of today's starvation is due to political issues, on a global scale we are going to have to be able to produce more on less land. This is a real challenge for agricultural research and a reason that we must do everything we can to preserve prime farm land.

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[2]Ag Issues Center Report on the Value of California agriculture.

The highly efficient food systems that have evolved in the United States and California in the past fifty years have been of most benefit to the consumer. In 1950 the average person spent 22 percent of his or her disposable income for food. Today he or she spends 11.8 percent. People with lower incomes benefit even more from the world's lowest food costs because they spend a higher amount of their income for food. If we decrease our ability to produce food efficiently, the greatest impact will be on the lower income, urban-based parts of our society.

Agriculture can also address global environmental concerns in addition to helping to maintain open space in an economically feasible way. There is a potential role for agriculture to help society deal with the global climate change issue. Although there continues to be a debate as to whether there is global warming, there is no doubt that we have substantially increased the level of CO^2 in the atmosphere. It is unlikely that we will reduce our dependency on energy and it is likely that other less developed nations, such as China with the world's largest coal reserves, will increase energy consumption in order to improve their standard of living. Agriculture can be a source of biomass for energy production so that we recycle the existing CO^2 rather than digging up more fossil fuel and adding to the greenhouse gases. Ethanol is already being produced from corn and it will be used as an important component of fuels in cities which have failed to meet current clean air standards. To be used on a larger scale and in a way in which there is a net energy gain, we need to develop the technology to more efficiently separate alcohol from water after fermentation.

What strategies can be used on a federal and state level to keep agriculture in a proactive role. One, we need to maintain and even increase our investment in research. In this State, which has been number one in agriculture for the past fifty years, we invest less than 0.01 percent of the farm gate value of agriculture in research. If we are to maintain a competitive advantage in the international markets in the NAFTA and GATT freer trade environment, we need to have a production and post harvest food and fiber system which is efficient, economically viable, environmentally responsible and safe. And all of this will have to be done on less prime agricultural land. We must invest now if we are to be able to reach these multiple and very challenging roles in the future.

We must also increase the agricultural literacy of the public. All of us have a role to play, whether we are in research, education of undergraduates and graduate students, or in extension. I am sure Henry Voss will have some comments on the proposed agricultural relations program funded by an industry wide assessment. Although it has received mixed reviews, I think it is an important step in the right direction. In today's world where the media seems to be hell bent to destroy or discredit individuals or institutions, including California agriculture, I think it is essential that we have a proactive program which presents agriculture enhances the quality of their lives. We are a solution to many of the concerns facing Californians whether they be environmental, economic, or health related.

CALIFORNIA FERTILIZER ASSOCIATION'S PERCEPTIVE OF MAINTAINING PROACTIVE ROLES FOR AGRICULTURE

Steven R. Beckley, Executive Vice President
California Fertilizer Association

Today, production agriculture and the industries that serve it must take a leadership role in protecting the environment, workers, and public, while also producing a product that is economical to the customer and profitable to the farmer. This is a big order in today's society and the only ones to make that change are ourselves.

The mission of the California Fertilizer Association (CFA) is to enhance the business environment for the fertilizer industry and ag chemical and fertilizer retailer in California. The leadership and membership of the association has chosen to carry out that mission by creating proactive programs and implementing them both on a voluntary basis and through legislation.

Current examples of CFA proactive programs are:

1. Anhydrous Ammonia Transportation Safety Program
2. Facility Guidelines To Protect Water Quality
3. Certified Crop Advisor Program
4. Fertilizer Research and Education Program
5. Community Outreach Program for Agri Dealers

These programs, combined with an ongoing education program that provides the participants with up-to-date knowledge is the core of a proactive association.

What does it take to be proactive:

1. Forward looking membership.

2. Intelligence on industry and society trends.

3. Commitment from membership to carry out programs.

4. Fact based information on what is possible.

5. Good working relationship with regulators and legislators.

Why should we be proactive and not wait for the next law or regulation? Because we know what our industry needs and can accomplish it in the most economical fashion. Government is necessary in some cases to be proactive, such as the Fertilizer Research and Education program.

Some points to consider when developing proactive programs are:

1. All impacted parties and regulators must be involved.

2. Communicate with all regarding development of program.

3. Research what has already been done.

4. Use performance based standards when possible (Stay away from prescriptions).

5. Get feedback on what you are doing.

6. Take the lead - act instead of react.

7. Control the agenda if possible.

8. Educate your members on how to implement programs.

Most importantly, make changes where it is necessary and make sure you develop programs that accomplish the goals intended and allow the industry to continue to use the products needed.

Being proactive is not easy, it is easier to complain and fight existing regulations. It is not cheap, as you are asking an industry to make investments, the dividends are not always as clear or concrete as they would like.

CFA made a commitment to be a proactive and forward looking association about 6 years ago at a long range planning session. At that time I warned the Board of Directors that we would lose members as we took aggressive proactive stances on some issues. Was I ever wrong, we have not lost a member because of our programs. I get phone calls asking how to do it, what is required, and when is the deadline, but no member resignations. I am very proud of the CFA membership in that they have seen the future and are preparing for it.

I challenge you to take your segment of the industry forward, let's stop complaining and do what is right. Let's not put our heads in the soil but instead be leaders in making the changes necessary.

California Farm Bureau Federation
1601 Exposition Boulevard • Sacramento, CA 95815 • Telephone (916) 924-4000

SUMMARY OF REMARKS
DOUGLAS W. MOSEBAR, SECOND VICE PRESIDENT
CALIFORNIA FARM BUREAU FEDERATION
TO THE
THE AMERICAN SOCIETY OF AGRONOMY
CALIFORNIA CHAPTER
1994 ANNUAL MEETING
JAN. 24, 1994

"FARM BUREAU'S STRATEGY FOR FUTURE CHALLENGES"

California agriculture will reach a critical turning point in 1994. The traditional challenges posed by the acts of mother nature (floods, freezes and droughts) have been combined with new challenges ---- man-made acts (Endangered Species Act, Clean Air Act, Clean Water Act and Central Valley Project Improvement Act).

California farmers and ranchers have passed from an era when they could count on productive soil, abundant water and technological advances to overcome challenges. Today, the demands and uncertainties of agriculture have never been greater because of other forces not encountered by our forefarmers.

The state's explosive population growth, combined with new environmental regulations, have changed the dynamics considerably. In the state's first comprehensive population forecast based on the 1990 federal census, officials project that California will add an average of 667,000 people --- almost as many as live in San Francisco --- every year between 1990 and 2040. This growth will place greater pressures on the state's natural resources, including its best farmland which has already lost 3 million acres between 1978 and 1987.

Farmers have been hit with restrictions relating to pesticides, wetlands, endangered species, new federal Bay-delta water quality standards, PM 10 requirements and new diesel fuel standards, just to name a few.

California agriculture's ability to address many of these and other issues will determine in large part the complexion of the industry into the 21st century. How will we respond to the challenges?

Much of Farm Bureau's success over its 75-year history has been in bringing together the state's diversified farming interests to share ideas, develop strategy and seek consensus on solutions. With the shrinking farm population, it has never been more important to have a unified industry. But agricultural unity, alone, will not assure our future success.

California agriculture must build more coalitions outside of the industry. Farm Bureau has been building new alliances in a number of important areas --- ag education efforts to seek and instill ag awareness and education in our schools. Our governmental affairs and nationals affairs programs seek to form alliances with state and national policy makers. Farm Bureau has also formed coalitions with the environmental community through our Office of Environmental Advocacy.

The role of farmers and ranchers today has changed --- not only must producers be adept at farming and ranching, we must be more involved than ever in Sacramento and Washington D.C.

Our legislative districts have become more urban. Fewer and fewer legislators understand our problems or appreciate our contributions. It has underscored the importance of making contacts with legislators in the district offices, and in our state and nation's capitols.

Farm Bureau recognizes the need to take a progressive approach to "sell" agriculture in ways that we have not done in the past. Messages that tell the public how important we are, how big we are, how privileged we are --- do not advance our cause. The fact is as long as grocery store aisle are full of inexpensive food, people won't pay much attention to our problems or support our solutions.

Agriculture needs to emphasize that we are more than farms and food. We are jobs, open space and wildlife habitat. We need to be thinking in terms of selling the other benefits. The University of California economic study last year indicated that one in ten jobs in the state is related to agriculture. Southern California has nearly double the farm-related employment as other agricultural regions. Job creation is an issue that hits home with the public, especially in light of the state's current recession.

Farm Bureau has identified areas where we have common goals with environmental groups. This year, we worked with the Sierra Club on a farmland monitoring and mapping program in Yolo County. We joined the Sierra Club in legal action to challenge land use decisions in Merced and Tuolumne counties. One successful program in Modoc County, built by a coalition of regulators, farmers, ranchers and environmental groups, has helped solve a complex problem in the Goose Lake basin. A total watershed management plan has been adopted that achieves the balance of protecting fish and preserving farming. Instead of knocking heads with our adversaries, we have put our collective heads together to work on solutions to environmental problems. These efforts need to be duplicated and multiplied.

That will be the trend of the future in California agriculture. We have many positive stories to tell. It is up to us to take charge and spread those stories to as many people as possible.

Henry J. . Voss, Secretary of Agriculture

The American Society of Agronomy
"CDFA Perspective on Maintaining a Proactive California Agriculture"

Greeting:
GOOD MORNING DISTINGUISHED GUESTS, MEMBERS AND FAMILY OF THE AMERICAN SOCIETY OF AGRONOMY.

1994 IS DEFINITELY A YEAR FOR GREAT AND VALUABLE OPPORTUNITIES FOR ADVANCEMENTS IN AGRICULTURE. AT THE CLOSE OF 1993, MAJOR CDFA ACCOMPLISHMENTS PROVIDED HEAD STARTS FOR A SAFER ENVIRONMENT AND STRONGER AGRICULTURAL ECONOMY IN WHICH TO PRODUCE CALIFORNIA'S LUSH BOUNTY.

IT IS IMPORTANT TO NOTE LAST YEAR'S MAJOR ACCOMPLISHMENTS IN ORDER TO UNDERSTAND WHERE AGRICULTURE IS HEADING AND TO INSURE A PROACTIVE, SUSTAINABLE, AGRICULTURAL ENVIRONMENT.

AT THE CLOSE OF THE YEAR, CALIFORNIA, WITH THE PASSAGE OF NAFTA, WAS GRANTED A GIFT OF 30,000 TO 40,000 NEW JOBS. NAFTA WILL TAKE CALIFORNIA AGRICULTURE BEYOND THE STATUS QUO AND INTO A FUTURE OF MORE TRADE OPPORTUNITIES WITH MEXICO AND OTHER NATIONS.

BECAUSE OF THE OPENING UP OF WORLDWIDE MARKETS, WE EXPECT INCREASED EXPORT OPPORTUNITIES FOR MANY OF CALIFORNIA'S COMMODITIES.

THE CALIFORNIA RICE INDUSTRY WILL EXPORT MORE THAN 80 MILLION DOLLARS OF RICE TO JAPAN, THANKS TO THE SIGNING OF GATT AND PROACTIVE STEPPED-UP MEASURES IN THE PRODUCTION OF VIABLE SAFE PRODUCTS COMPATIBLE WITH THE EXPECTATIONS OF JAPENESE CONSUMERS.

NAFTA AND GATT RULES ON PLANT AND ANIMAL HEALTH PROTECTION WILL BE AN IMPORTANT MODEL FOR REDUCING ONE OF CALIFORNIA AGRICULTURE'S MOST FORMIDABLE TRADE BARRIERS AROUND THE WORLD: UNFAIR QUARANTINES.

NAFTA NEGOTIATORS AGREED THAT RULES TO PROTECT PLANT, ANIMAL AND HUMAN HEALTH MUST BE BASED ON SCIENTIFIC PRINCIPLES AND RISK ASSESSMENT; MUST BE APPLIED ONLY TO THE EXTENT NECESSARY TO PROVIDE A COUNTRY'S CHOSEN LEVEL OF PROTECTION; AND MUST NOT RESLUT IN UNFAIR DISCRIMINATION OR DISGUISED RESTRICTIONS ON TRADE.

THE AGREEMENT FOR CALIFORNIA CONSUMERS AND FARMERS ALIKE ENABLES US TO MAINTAIN OUR HIGH QUALITY STANDARDS AND APPLY THEM EQUALLY TO OUR OWN PROCEDURES AND OUR NAFTA TRADING PARTNERS.

WE EXPECT TO USE ADEQUATE U.S. RESOURCES TO MAINTAIN QUALITY CONTROLS ON ALL FOOD, ANIMALS AND PLANTS COMING INTO THE COUNTRY TO PREVENT THE INTRODUCTION OF PLANT PESTS SUCH AS EXOTIC FRUIT FLIES AND ANIMAL PESTS SUCH AS BRUCELLOSIS, AND OF COURSE TO CONTINUE PROVIDING A WHOLESOME AND SAFE FOOD SUPPLY.

CDFA PLACES GREAT IMPORTANCE ON MAINTAINING A NATURAL BALANCE BETWEEN ENVIRONMENTAL PROTECTION AND AGRICULTURAL PRODUCT DEMAND. THE PAST YEAR HEIGHTENED OUR AWARENESS OF HOW IMPORTANT IT WAS TO DEAL WITH DEVASTATING AGRICULTURAL PESTS IN A SAFE AND EFFICIENT MANNER.

WE EXPLORED, AND SUCCESSFULLY UTILIZED NEW AND ENVIRONMENTALLY STABLE WAYS TO FIGHT SUCH INSECTS AS THE COTTON BOLL WORM AND BOLL WEEVIL AND THE NOTORIOUS MEDITERRANEAN FRUIT FLY.

THREE YEARS HAVE PASSED SINCE THE COTTON BOLL WEEVIL HAS BEEN FOUND IN THE STATE OF THE BOLL WORM HAS DECREASED FROM 3,239 NATIVE MOTHS FOUND IN 1990 TO 51 NATIVE MOTHS THIS PAST YEAR. MOREOVER, CDFA HAS UNDERTAKEN A MAJOR TASK OF ERADICATING THE MEDITERRANEAN FRUIT FLY AT A NUMBER OF LOCATIONS IN THE LOS ANGELES AREA.

THESE 1993 MAJOR ACCOMPLISHMENTS IN AGRICULTURE, ENHANCE THE CURRENT CHALLENGES WE WILL FACE THIS YEAR AND YEARS TO COME. A GROWING ECONOMY AND ENVIRONMENTALLY SOUND PRACTICES WILL BE NECESSARY FOR THE PRODUCTIVE FUTURE OF CALIFORNIA'S AGRICULTURE.

CDFA IS PRESENTLY INVOLVED IN NEW PROGRAMS THAT ARE SERVING THE NEEDS OF PLANT AND SOIL STABILITY. ONE OF OUR PROGRAMS THAT IS IN FULL-SWING AND MOST IMPORTANT, IS THE FERTILIZER RESEARCH AND EDUCATION PROGRAM (FREP). THIS PROGRAM CURRENTLY WORKS TO PROTECT THE SOIL AND WATER ENVIRONMENT, FROM HARMFUL NITRATE LEVELS.

ONE PROJECT UNDER THE PROGRAM THIS YEAR WILL BE FERTILIZER BEST MANAGEMENT PRACTICES EDUCATION.

THIS PROJECT FOCUSES ON RAISING THE AWARENESS OF GROWERS AND CONSULTANTS. THE ADVANTAGE OF MOST, IF NOT ALL OF THE BEST MANAGEMENT PRACTICES TAUGHT, ARE THAT THEY NOT ONLY PROTECT THE ENVIRONMENT, BUT THEY ARE USUALLY THE MOST PROFITABLE PRACTICES FOR GROWERS.

(A FARMER WHO OVER FERTILIZES WITH NITROGEN, OR THER NUTRIENTS MAY GET VERY HIGH YIELDS BUT HIS OR HER ACTUAL PROFITS ARE LESS THAN THOSE OF A PERSON WHO FERTILIZES TO OBTIAN THE MOST PROFIT.)

THE FREP PROGRAM ALSO MONITORS CHANGES IN SOIL FERTILITY, CROP, PEST AND ECONOMIC PARAMETERS IN FOUR TYPES OF FARMING SYSTEMS. INCLUDING: CONVENTIONAL 2 YEAR ROTATION, CONVENTIONAL 4 YEAR ROTATION, ORGANIC 4 YEAR ROTATION AND A LOW-IMPUT 4 YEAR ROTATION.

EFFICIENT USE OF FERTILIZERS RESULTING IN MAXIMUM PLANT PRODUCTIVITY AND MINIMAL ENVIRONMENTAL HARM IS DESIRABLE BOTH TO THE AGRICULTURAL COMMUNITY AND MEMBERS OF THE GENERAL PUBLIC WHO RELY ON GROUNDWATER AS A SOURCE OF DRINKING WATER.

AS IT IS KNOWN, THE SUCCESSFUL FUNCTIONING OF AGRICULTURAL SYSTEMS DEPENDS ON THE TIMELY DELIVERY TO PLANTS OF NITROGEN AND OTHER NUTRIENTS FROM MINERAL FERTILIZERS AND FROM DECOMPOSITION OF ORGANIC RESIDUES, BOTH OF WHICH ARE STRONGLY INFLUENCED BY MICROBIAL ACTIVITY IN SOILS.

FURTHER, NEW AND INNOVATIVE PROJECTS ARE COMMITTED TO CONTROLLING AND ERADICATING DESTRUCTIVE AGRICULTURAL PESTS, USING ENVIRONMENTALLY SOUND METHODS. STERILE INSECT RELEASES HAVE BEEN OUR MAIN STRATEGY IN CONTROLLING RUINOUS FLY'S, WORMS, AND WEEVILS. CDFA UTILIZES THIS METHOD EXTENSIVELY. MOREOVER, IT IS A PREFERRED, SAFER AND EFFECTIVE METHOD OVER PAST ERADICATION PROCEDURES. THE CONTINUATION OF THESE TYPES OF ERADICATION EFFORTS WILL SUCESSFULLY INCREASE CROP YIELDS AND RESULT IN IMPORTANT BOOST IN CALIFORNIA'S ECONOMY.

PROATIVE AGRICULTURE DEPENDS ON THE ADVANCEMENT OF AGRICUTURAL TECHNOLOGY, KEEPING IN BALANCE WITH THE ENVIRONMENT. IN DOING SO, THE AGRICULTURAL INDUSTRY CAN GROW ECONOMICALLY WITH THE PROMISE OF A FERTILE FUTURE.

Agricultural and Environmental Issues: Where does California Stand?

Roland D. Hauck
Senior Scientist (retired)
Tennessee Valley Authority

Public focus on the contribution of agriculture to environmental stress has progressively increased over the past two decades. Prominent in this focus is nitrogen, which, as a nutrient, is one of the most important of all crop production factors, but when regarded as a contaminant, is an element of environmental concern.

Responding to this concern while meeting the continuing increase in food and fiber demand of an expanding world population is an overarching challenge for agriculture. World population will exceed 6 billion people by the year 2000. The nitrogen needed to grow the food and fiber required by this population will be obtained partly from that circulating through soil/plant systems and partly from new additions from the atmosphere. These additions will result mostly from increased production of grain legumes, which obtain part of their nitrogen through fixation of molecular nitrogen, and from increased production of nitrogen fertilizers, for use mainly on cereal grains and fiber crops. Currently, >75 Mt of fertilizer nitrogen are added to world soils to produce annually about 1,900 Mt (million metric tons) of cereal grains. Production of about 60 Mt of grain from legumes adds an estimated 90 Mt of biologically fixed nitrogen annually. An additional 50-75 Mt of nitrogen is added each year via biological dinitrogen fixation to the world's permanent meadows and pastures.. These large amounts of nitrogen are concentrated in <11% of the earth's total land surface, resulting in an increase in the total nitrogen content of soils, waters, crop residues, and industrial and municipal wastes. And the amount of nitrogen input, regardless of sources, must continually increase as the numbers of people increase and their diets and standards of living improve.

The annual application of fertilizer nitrogen to U.S. soils has been relatively constant since 1980 (about 10 Mt) but harvested crop acreage has decreased about 10%. Over the past two decades, nitrogen fertilizer additions to California soils have averaged 575.000 tons annually,. Though the amount applied varies considerably with kind of crop, the total amount of nitrogen applied is equivalent to about 235 lb per harvested acre. Nitrogen used in crop production and that derived from concentrated animal waste and urban sewage have reportedly lead to elevated groundwater nitrate levels in several regions of California. Contamination of drinking water supplies with nitrate and organic chemicals and water usage are major environmental concerns associated with California agriculture.

The questions raised here relate to California's current and future involvement in domestic and world food and fiber production, and to how Californians will balance environmental versus agricultural production and profit goals. The questions are raised first by examining the concept of sustainability, then in terms of key policy issues.

A workable balance between production and environmental objectives considers four main characteristics of sustainable agricultural systems. Such systems, regardless of the level and nature of their inputs, are (i) productive and economically viable over time,(ii) environmentally conscious, (iii) politically and socially acceptable, and (iv) stewardship-minded.

To remain economically viable, agriculture must continually be responsive to changes in costs and supply and demand. Environmental consciousness for a productive ecosystem requires knowledge of costs and benefits and what compromises need to be made among often conflicting goals. To be socially and politically acceptable requires recognition of current perspectives about agriculture and the environment and the willingness of producers and consumers to make reasonable compromises. The fourth characteristic of a sustainable agriculture -- stewardship -- encompasses the conservation of natural resources, specifically soils, waters, energy, and raw materials used for agricultural inputs.

The agenda for agriculture now is driven in part by many in the public sector whose primary interest is not agriculture, other than as consumers of food and fiber. Because of the broad diversity of opinions and values related to agricultural production, compromise is requisite to working out reasonable approaches to agricultural sustainability.

Producers normally emphasize the production and profit characteristics of sustainability, recognizing, however, the long-term benefits of good stewardship and becoming increasingly aware of the costs of violating social and political acceptability. Consumers, accustomed to a variety of abundant food supplies at relatively low cost, emphasize environmental protection, sometimes forgetting or being misinformed about the wealth of knowledge and technology used in agricultural production. Where the emphasis should be is determined by consensus and changes with time, as time alters needs, values, and perspectives.

What will be the objectives of California agriculture during the 21st century? To what extent will it contribute to the state economy, to domestic needs, to the nation's agricultural commodity trade balance, to the world need for food and fiber? As the world intensifies its agricultural production as required to meet population demands, will California accompany this trend? Will public perspectives and concerns for environmental protection permit the current if not increased level of agricultural production in California? These questions should not be answered without careful consideration of reasonable arguments for and against production controls, for and against approaches toward environmental protection, based on he best knowledge already at hand or within reach.

Perhaps changes in the mix of agricultural production may become necessary. Consider, for example, cotton, rice, soybeans and vegetables. About 29% of U.S. cotton is grown in California

(13.8% of U.S. cotton acreage). About 14.5% of the world's cotton is produced in the U.S.; this cotton accounts for almost 30% of the world cotton export market. Clearly, California contributes significantly to domestic and world cotton supplies, and cotton contributes well over $1 billion to California's agricultural economy. On the debit side, there are environmental concerns related to use of nitrogen, irrigation water, and organic chemicals for intensive cotton production.

Almost 50% of the world's soybeans are produced on 60 million acres of U.S. farmland, of which <2% is in California. Therefore, it may be prudent to consider factors other than California's contribution to world food supplies when assessing the role of soybean production in California agriculture.

Among the rice-growing states, California maintains the highest average per acre rice yields and accounts for 21% of U.S. rice production. However, total U.S. rice production is about 3% of total world production and U.S. rice exports comprise only 0.5% of the world trade in rice. Considering these facts, the benefits of California rice production for domestic consumption might be balanced against alternative uses for the water needed for flooded rice production.

More than one-half (57.2% during 1990) of total U.S. vegetables for fresh market and processing are grown in California on about 850,000 acres of land (32.2% of total U.S. acreage for vegetables). Almost one-half (47.2%) of the total dollar value of U.S. vegetables is returned to California's economy (during 1990, vegetables produced in California were valued at >$2.64 million). Clearly, intensive vegetable production in California can be judged sustainable and economically viable over time but can only be achieved at current levels with large farm inputs, including irrigation water, Technologies, such as use of trickle irrigation, can decrease the amount of water used and, therefore, movement of contaminants to groundwater. The effectiveness of improved practices and technologies to lessen the risk of environmental stress, the desire for plentiful quantities of high quality produce, the effect of production change on the vegetable distribution sector in California and elsewhere, these all factors that Californians can consider when balancing the positive and potential negative impacts of vegetable production in California.

The above examples are given solely to illustrate to a very small degree the kind of in-depth analysis that can be made to determine the long-term sustainability of a particular crop production system. Of course, for a detailed analysis, many other relevant factors must be considered. All such factors can be considered in terms of the main characteristics of sustainability as described above.

Strategies for achieving production and environmental goals with respect to nitrogen use were outlined in a 1989 report *Nitrate and agriculture in California* submitted by the Nitrate Working

Group, California Department of Agriculture. One objective of the recommended strategies is to identify nitrate-sensitive areas in California, list priority areas, and establish nitrate control programs for these areas. Such control programs, if required, should be consistent with the characteristics which describe sustainable agricultural systems and should give detailed consideration to four key policy questions.

The questions are: *What are the goals?* (Are they realistic? What means for reducing environmental risk and what production practices are appropriate, manageable, and consistent with acceptable compromise among production, profit, environmental, and conservation goals?) *Who is involved?* (What is the appropriate role of government and of public and private sector interest groups?) *Who pays?* (What are the direct and indirect costs of a given level of agricultural production at a given level of environmental and/or health risk? Who benefits or who has the right to benefit from meeting production and/or environmental goals? How are costs shared among producers and consumers?) *Who decides?* (Answer to this pivotal question is determined by considering costs/benefits and the nature and extent of governmental involvement.)

Californians are not alone in wrestling with these questions. Answers will be sought both on state and national levels. Now involved in the agricultural agenda are questions about agricultural versus urban land use, water rights, wildlife habitat preservation, surface water and groundwater protection, and air quality, in addition to the traditional questions related to maintaining the productive capacity of the nation's soils.

An acceptable balance between production and environmental protection needs requires producers and consumers both well-informed and sensitive to each others' values and perspectives. Knowledge, understanding, and sensitivity are the keys to acceptable compromise, to the building of workable consensus as California and the nation prepare for the challenges of the 21st century.

AGRICULTURE AND THE REAUTHORIZATION OF THE CLEAN WATER ACT
by
Dennis W. Westcot[1]

Two major bills to reauthorize and amend the Federal Water Pollution Control Act (Clean Water Act) were introduced in June 1993:

S.1114 - The Water Pollution Prevention and Control Act of 1993 was introduced by Senator Baucus (D-Montana) and Senator Chafee (R-Rhode Island). This bill is to amend and reauthorize the Clean Water Act; and

H.2543 - The Nonpoint Source Water Pollution Prevention Act of 1993 was introduced by Representative Oberstar (D-Minnesota). This bill is to improve the nonpoint source provisions contained in Section 319 of the existing Clean Water Act.

Hearing have just begun on both of these bills with major movement and debate next year. Regardless of when, agriculture will be a prominent topic of debate.

S.1114

Senator Baucus in his opening statement on S.1114 said

Our goal is simple. We want to improve the Clean Water Act . . . . To accomplish this, our bill . . . . would establish new programs for controlling nonpoint source pollution and watershed planning.

EPA Administrator Carol Browner, in her testimony, told the Senate Committee

. . . if we collectively assure better nonpoint source management through a reauthorized Clean Water Act, the legislation will be a success.

Browner stressed voluntary targeted approaches in nonpoint source pollution management backed up by the ability to address repeated noncompliance.

Key provisions of S.1114 that deal with agriculture are:

- Existing state nonpoint source pollution control plans are to be revised and upgraded, to prescribe more specific best management practices, and to implement site-specific management plans for existing agricultural sources in impaired watersheds.

- A new initiative is introduced for voluntary watershed planning to correct pollution in impaired watersheds. States identify impaired waters and watersheds and must develop watershed plans and set timelines for implementation to assure that water quality goals are met.

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Geoffrey Grubbs, Director of the Office of Water Assessment and Watershed Protection Division, testified for EPA that *their experience in nonpoint source management under Section 319 indicates that the watershed approach does work, but the basic framework of the Clean Water Act needs to be "upgraded" and the watershed approach strengthened.* In addition to a stronger watershed framework, he outlined four basic principles to guide the focus on agriculture during reauthorization:

- *continue to focus on voluntary, targeted approaches, but supplement them by enforceable requirements that can be triggered as necessary*;

- *establish clearer performance expectation and technical baselines*;

- *focus water quality program on aquatic ecosystem protection, not just on the water column*; and

- *stress pollution prevention.*

Grubbs spoke about the necessity of strengthening state nonpoint management plans and updating their nonpoint assessments and how the watershed approach would be applied. He said

> *For example, states do not share an understanding of the baseline management measures that are available, and there is no generally agreed upon schedule to guide state progress. There is no basis in Section 319 for gauging the success of state nonpoint source programs or for EPA to step in where states fail to act, no matter how severe the water quality problem may be.*
>
> *Section 319 should be amended to bolster state nonpoint source programs in concert with a watershed protection approach. As a part of a watershed protection approach, state should specifically identify those waterbodies and their watersheds that are impaired or threatened by nonpoint sources.*

He concluded his presentation with these words

> *Polluted runoff poses a challenge that federal agencies, states, local governments,and the private sector must meet if we are ever to realize the full promise of the CWA. The problems are different and more subtle than those of the past., but they are not insurmountable. Public education, clear definition of good practices, and a commitment by state and federal agencies to water quality values will carry us a long way.*

H.2543

H.2543, the Nonpoint Source Water Pollution Prevention Act of 1993 looks exclusively at the improvement of the nonpoint source control provisions contained in Section 319. It is likely that this legislation would be included in reauthorization legislation for the Clean Water Act.

H.2543 focuses on watersheds and encourages "good actors", those who comply to carry out clean-up plans, and **requires states to have fall-back enforcement legislation** for "bad actors", those who "refuse to clean up and who try to profit while the good actor competitors comply."

The key components of H.2543 are:

- EPA must publish guidance for state revision of Section 319 plans.
- **EPA must revise the Coastal Zone Management Act BMPs to extend them to noncoastal areas.**
- EPA must **establish nonpoint source water quality criteria** within three years identifying numerical pollutant concentration limits for, in order of priority of development: **(a.) nutrients** (b.) pesticides (c.) sediments (d.) habitat needs and (e.) hydromodifaction; and
- EPA must set specific timelines for states to identify and prioritize target watersheds and develop and issue guidance and regulations.

Both bills focus on nonpoint sources; therefore, agriculture is likely to be a major focus of debate. The author of H.2543 said that

> *when the debate heats up over nonpoint source pollution, agriculture will be scrutinized. EPA reports indicate 60 percent of the nation's threatened surface waters are affected by farming practices. Although urban development, marinas, dam building, and the like contribute to nonpoint source pollution, agriculture is seen by many people as the most significant source, so **it is not a question of whether agriculture will be singled out - - but how**.*

The above summary was pruned from the following sources:

Finally, Congress Considers CWA Bills. Runoff Report - Watershed Information Network News, Vol. 1, No. 2, Summer/Fall 1993. National Nonpoint Source Federation, Kansas City, Missouri.

Keeping Current. Water Resources Newsletter of the University of Wisconsin Cooperative Extension Service. April 1993.

Nonpoint Source Water Pollution Prevention Act of 1993. House of Representative Bill No. 2543, 103rd Congress, First session. Washington, D.C. 28 June 1993.

Reauthorizing the Clean Water Act, Nonpoint Source News - Notes No. 31, August-September 1993, US EPA.

Testimony of Carol M. Browner, Administrator, U.S. Environmental Protection Agency before the Subcommittee on Water Resources and Environment of the Committee on Public Works and Transportation, U.S. House of Representatives. 5 May 1993.

Testimony of Carol M. Browner, Administrator, U.S. Environmental Protection Agency before the Subcommittee on Clean Water, Fisheries and Wildlife of the Committee on Environment and Public Works, United States Senate. 16 June 1993.

Testimony of Geoffrey Grubbs, Director, Assessment and Watershed Protection Division, Office of Water, U.S. Environmental Protection Agency before the Subcommittee on Clean Water, Fisheries and Wildlife of the Committee on Environment and Public Works, United States Senate. 14 July 1993.

Water Pollution Prevention and Control Act of 1993. U.S. Senate Bill No. 1114, 103rd Congress, First session. Washington, D.C. 15 June 1993.

COASTAL ZONE MANAGEMENT ACT

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The Coastal Zone Management Act (CZMA) of 1972, under the jurisdiction of NOAA (National Oceanic and Atmospheric Administration) allowed states to develop programs to manage and protect their coastal resources. To receive federal funds, the states not only had to show that they had such programs, but also that such programs were backed up by enforceable policies concerning water uses and surrounding land.

The CZMA was based on a national concern that coastal resources were being threatened. The first item it declared as a national policy was "to preserve and protect and where possible, restore or enhance the Nation's coastal resources for this and succeeding generations".

The "coastal zone" includes coastal waters and those lands that have a direct and significant impact on coastal waters. Areas to be protected include wetlands, estuaries and beaches.

Design and implementation of coastal zone protection programs was delegated to the states, although programs must receive final federal approval. The CZMA also required states to use extensive participation and input from citizens and business groups to prepare these programs.

While water quality and nonpoint source pollution was not an integral part of the original act, it is the centerpiece of the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA). States now have procedural requirements as well as financial incentives, to regulate land uses and NPS pollution to protect coastal water quality.

As part of this act, NOAA and Environmental Protection Agency (EPA) developed the "Program Development and Approval Guidance", which is a draft document for coastal states for the development and implementation of Coastal Nonpoint Pollution Control Programs (CNPCP's). This document is commonly called the "approval" of "program" guidance, and was finalized early 1993.

As part of the CNPCP, NOAA and EPA are also evaluating the impact of land use activities throughout the coastal watersheds. If the boundary of an existing coastal zone program is found to be inadequate for controlling significant sources of nonpoint source pollution, NOAA and EPA will recommend expanding it. Although a state is not bound by this recommendation, it must still demonstrate the ability to effectively control nonpoint sources that drain into coastal waters. This may require the state to develop other coastal management areas. These could be developed according to the criteria in the Approval/Program Guidance.

STABLE ISOTOPE IMAGING TO DELINEATE SOURCES OF GROUNDWATER CONTAMINATION

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Abstract. Shallow masses of groundwater in the southern Sacramento Valley have been characterized and delineated by exploiting the large variations in $\delta^{18}O$ and δD values of the water and in the apparent ^{14}C ages of dissolved bicarbonate. Pristine shallow groundwater in this area is derived from average meteoric precipitation and has $\delta^{18}O = -7.5$, low NO_3 concentrations (~ 5 ppm), and ^{14}C apparent ages of 2.6 to 5.0 ka. However, pumping is causing the replacement of the pristine groundwaters by younger surface waters that in the various subregions originate from one or a combination of several isotopically distinguishable sources. These sources include: (1) Surface waters from Cache and Putah Creeks, which have $\delta^{18}O > -6$ and plot to the right of the meteoric water line (abbr. MWL) along surface evaporation trends; (2) Water from the Sacramento River, which plots near the MWL at a low $\delta^{18}O$ value of -11, and has near-modern ^{14}C abundances; (3) Evaporated flood plain waters with elevated heavy isotope contents along with ancient ^{14}C apparent ages of >3 ka; and (4) Agricultural irrigation waters with $\delta^{18}O > -6$, young ^{14}C apparent ages of < 0.5 ka, and elevated nitrate contents (to 44 ppm or higher); these plot to the right of the MWL along vadose zone evaporation trends.

The irrigation waters mentioned above dominate groundwater recharge in many areas, where they pose an immediate threat to groundwater quality. This type of relationship is indicated in the Davis area, where good correlations have been found between elevated $\delta^{18}O$ values due to evaporation, reduced ^{14}C apparent ages indicating recent contact with surficial environments, and increased NO_3 concentrations. We suggest that flood irrigation and fertilization practices maintain nearly uniform water levels over an annual cycle, but are responsible for the NO_3 increases and the resultant progressive degradation of the water quality. This trend is exemplified by the increase in average nitrate levels in the Davis municipal well waters from <10 ppm in 1960 to 18 ppm today, as well as by non-linear secular increases in NO_3 concentrations in individual wells that have been repeatedly measured over time.

Contour maps of the $\delta^{18}O$ values can be used to "image" the locations, migration and mixing paths of these different water types. These maps elucidate the process whereby the irrigation waters enter the Davis municipal aquifer, notably as prominent plumes that intensify during summertime, when drawdown is greatest. As another example, a narrow, ~2 mile-wide tongue of high ^{18}O water derived from Putah Creek is infiltrating into surrounding groundwater. Deep, pumping-induced infiltration of young surface waters in the municipal aquifers of Davis and Woodland is also clearly indicated by a negative correlation between nitrate contents and ^{14}C apparent ages. The induced replacement of ancient, pristine groundwater by younger surface waters does not result in a permanent depression of the water table, but nevertheless is a heretofore unrecognized type of groundwater "mining".

INTRODUCTION

Groundwater pumping in California provides 46% of domestic water and 39% of agricultural irrigation (Spieker, 1984). Associated with this extensive groundwater use are several deleterious consequences whose severity increases over time, and which interfere with the use of this essential resource on a "sustainable" basis.

To combat these problems new and accurate information on the origin, age, source, and migration paths of groundwater is needed. Isotopic methods provide a well-understood but curiously underutilized means of obtaining this information. This study, centered in the southern Sacramento Valley, demonstrates the potential of the $^{18}O/^{16}O$, D/H, and ^{14}C isotopic systems to characterize surface and groundwater resources and to understand their age, origins, and the processes that affect them. We use these techniques to elucidate an important process of water quality degradation and to establish the likely origin of a non-point source contaminant.

BACKGROUND

Oxygen and hydrogen isotope ratios provide conservative natural tracers that are intrinsic to the water molecule. In the hydrologic cycle these ratios vary because of isotopic fractionation during phase changes. As a result, meteoric precipitation that originates in different regions from air masses with different temperatures, different percentages of condensation, etc. has distinctive isotopic ratios (e.g., Sheppard, 1986). The δD and $\delta^{18}O$ values (defined below) of most meteoric waters in the world conform to the global meteoric water line documented by Craig (1961a), notably $\delta D = 8\ \delta^{18}O + 10$. Thus, on a plot of δD vs. $\delta^{18}O$, the waters define a coherent trend with a slope of 8 and exhibit progressively lower contents of the heavy isotopes D and ^{18}O in colder regions, at higher altitudes, and/or with increasing geographic isolation from the coast. A reconnaissance study of stable isotope variations in the natural waters of California is provided by Ingraham and Taylor (1991). A detailed δD, $\delta^{18}O$, and ^{14}C data base for Sacramento Valley waters is provided by Davisson and Criss (1993) and Davisson et al. (1993a).

When meteoric water evaporates in surface water impoundments (reservoirs, rivers, ponds, etc.), kinetic isotope effects increase the δD and $\delta^{18}O$ values of the waters, causing them to plot along lines that trend away from the meteoric water line. Waters evaporated at the surface have characteristic slopes of about 5 on a graph of δD and $\delta^{18}O$, whereas the slope is approximately 3 if the evaporation occurs in the vadose zone (Barnes and Allison, 1983) .

An additional important property is that the hydrogen and oxygen isotopic ratios in cool groundwaters are conservative. Moreover, mixing of different waters produces linear trends between the δD or $\delta^{18}O$ values and the relative proportions of the endmember waters.

In short, significant isotopic variations in natural waters are commonplace, and are recorded in groundwater as signatures that remain invariant over time. The isotopic character of the groundwater is highly amenable to analysis and interpretation.

METHODS

All samples were collected in 15 or 30 ml glass bottles with air tight seals that prevent evaporation. Groundwater samples were collected from actively pumped, high capacity (500 to >2000 gpm) municipal and irrigation wells that mostly represent depths of 300 ± 250 feet below the surface. Surface waters were collected from flowing rivers, streams and canals.

The standard CO_2 equilibration (Epstein and Mayeda, 1953) and zinc-reduction methods (Coleman et al., 1982) were used to prepare the water samples. The oxygen and hydrogen isotope analyses were then made on a mass spectrometer at the Geology Department at the University of California, Davis. These analyses are reported in the usual δ notation relative to the SMOW isotopic standard, where $\delta = (R/R_{smow} - 1)1000$, R represents either the $^{18}O/^{16}O$ or the D/H ratio of the sample, and R_{smow} is either the $^{18}O/^{16}O$ or the D/H ratio of SMOW (Standard Mean Ocean Water; Craig, 1961b).

The ^{14}C sample bottles (125, 250, or 500 ml) were flushed ~30 seconds to one minute, after which approximately 4 drops of concentrated $HgCl_2$ were added to the sample to kill all biological activity in the water, and the bottle was capped with an air-tight seal. On a vacuum extraction line the dissolved inorganic carbon was liberated as CO_2 following acidification of the sample to pH < 1 with 100% phosphoric acid. Following conversion of the CO_2 to graphite, the ^{14}C concentrations were determined on the 10 MeV accelerator mass spectrometer at Lawrence Livermore National Lab. Percentages of modern ^{14}C are calculated relative to a NBS OX-1 standard that represents pre-nuclear testing, ^{14}C atomic abundances in atmospheric carbon dioxide. Apparent ages are calculated using a half-life of 5730 years (Walker et al., 1989).

RESULTS

Oxygen Isotope Map. In contrast to the simple eastward gradient of the water table (see Department of Water Resources, 1986), complex geographic variations occur in the $\delta^{18}O$ values of groundwaters in the southern Sacramento Valley (Fig. 1). Natural, shallow (to ~600 feet) meteoric ground waters in this area have uniform $\delta^{18}O$ values of -7.5‰ and ancient ^{14}C apparent ages of 2.6 to 5.0 ka. This type of water would be expected to dominate much of the shallow groundwater in this region. However, such pristine waters are now prevalent only in hilly terrane where intensive irrigation has not occurred. Such areas include the lowlands of the eastern Coast Range and the Dunnigan Hills, respectively located west and north of the study area (Davisson et al., 1993a). However, a smaller zone of this ancient, -7.5‰ water appears to originate in the Plainfield ridge, and continues generally southeastward beneath Davis in a sinuous band, which perhaps represents a boundary of contrasting permeabilities (Fig. 1).

In intensively irrigated areas, much of the natural meteoric groundwater is actively being replaced by groundwaters that have high $\delta^{18}O$ values (> -6.0‰). Such waters occur on the north, west and south sides of Davis (Fig. 1). Davisson and Criss (1993) provide a series of detailed $\delta^{18}O$ maps for different seasons that establish that these high ^{18}O waters are recharged irrigation waters that reside in the upper portion of the aquifer and increase their penetration depths below the Davis area during summertime, when drawdown of the water table is greatest (also see below).

High $\delta^{18}O$ water also occurs in an elongate, ~2 mile-wide band along Putah Creek (Fig. 1). This feature probably formed subsequent to the construction of Monticello Dam in 1957. Since that time, rather steady and unnatural flow of evaporated, high ^{18}O water that had been impounded by the dam has occurred along Putah Creek. The apparent lateral rate of penetration of this high ^{18}O water into the groundwater aquifer appears to be approximately 100 ft/yr, for the component perpendicular to the creek. This advance has been accentuated by groundwater pumping peripheral to the creek. However, as much as 50% of this apparent lateral advance probably represents the direct use of Putah Creek surface water recharged from irrigated fields on either side.

Origin of the High ^{18}O Component. The high $\delta^{18}O$ (~ -6.0‰) water beneath Davis has elevated nitrate concentrations (up to 44 ppm) and low ^{14}C ages of < 0.5 ka. In fact, in the Davis municipal

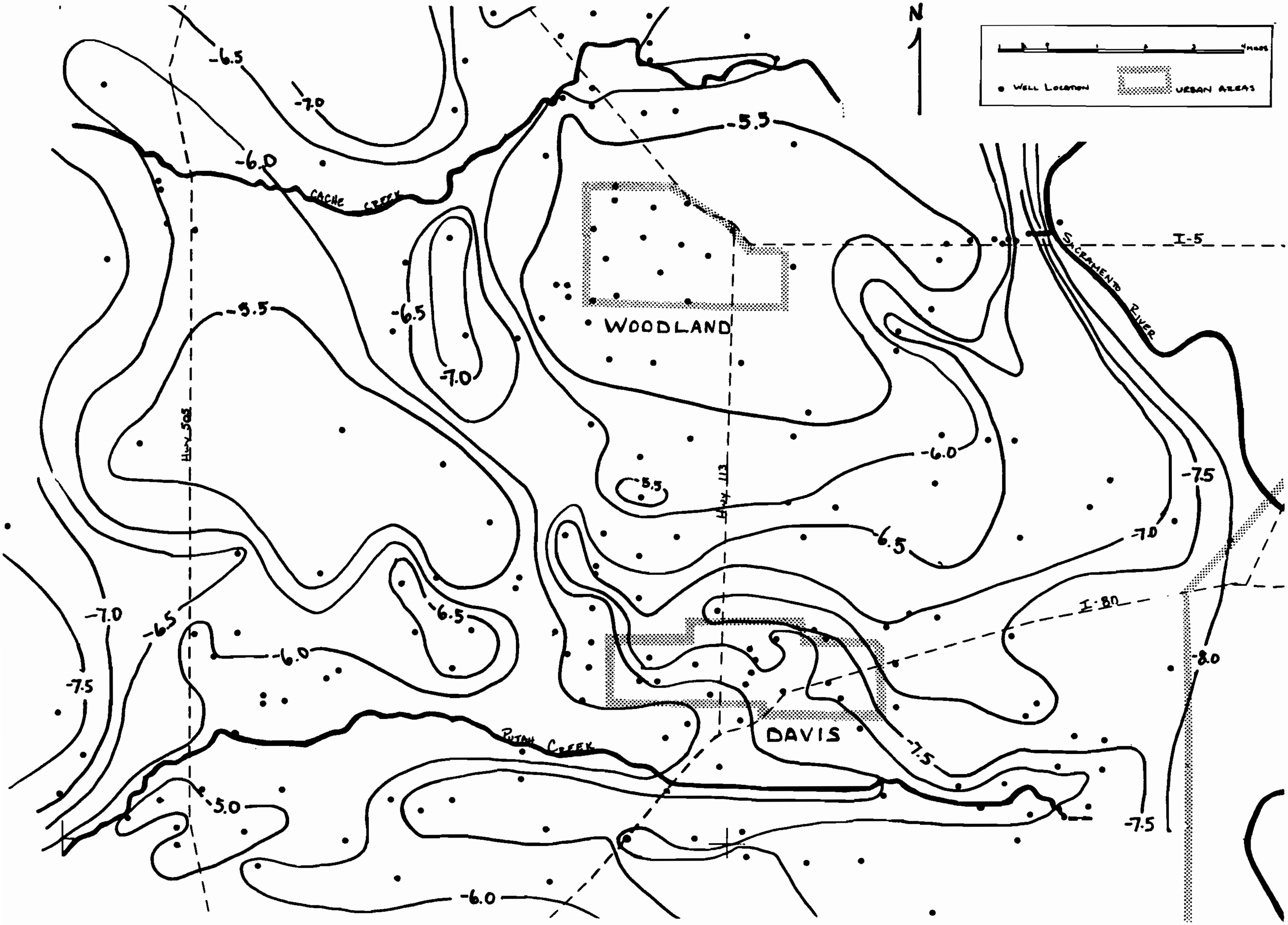

Figure 1. Contour map of $\delta^{18}O$ values of shallow groundwaters in the Davis and Woodland areas, as represented by high volume agricultural and municipal wells. Most samples were collected during the spring and summer of 1993.

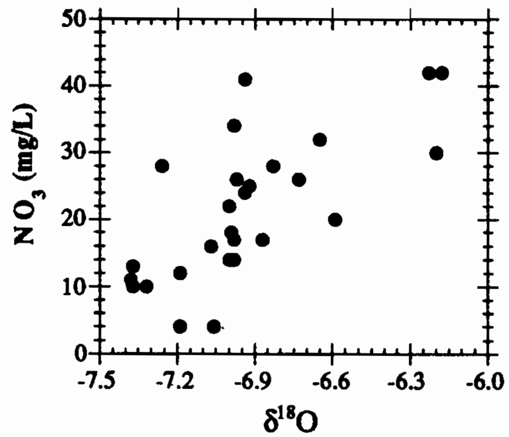

Figure 2. Graph of nitrate contents vs. the $\delta^{18}O$ values for shallow municipal groundwaters of the City of Davis. The correlation demonstrates mixing of pristine, low ^{18}O groundwaters with high nitrate waters enriched in ^{18}O due to evaporation.

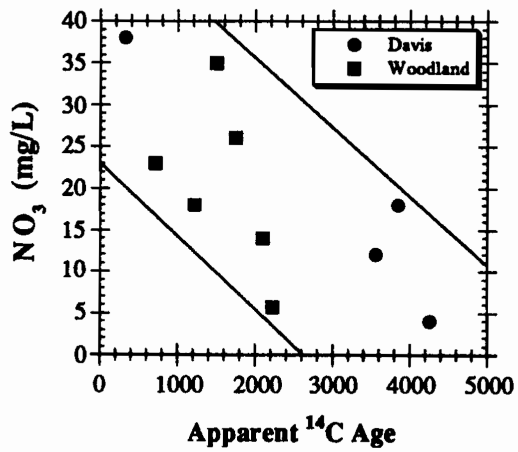

Figure 3. Graph of nitrate contents vs. the apparent age of bicarbonate for shallow municipal groundwaters of the cities of Davis and Woodland. The negative correlation demonstrates that mixing of modern, high nitrate waters with ancient pristine groundwaters occurs in both areas.

wells a very good correlation is observed between nitrate concentrations and the $\delta^{18}O$ values (Fig. 2, Davisson and Criss, 1993). Moreover, in the municipal wells in both Davis and Woodland, the nitrate concentrations show a strong negative correlation with the ^{14}C apparent ages (Fig. 3). These relationships indicate that agricultural irrigation water is mixing with the ancient pristine groundwater in these areas. The indicated characteristics for the irrigation water endmember include 1) high nitrate contents, consistent with their interaction with fertilizer and soils, and commonly involving the direct addition of anhydrous ammonia to the water ("fertigation"); 2) a modern ^{14}C apparent age, due to the exchange of the waters with atmospheric carbon having modern ^{14}C contents; 3) enriched ^{18}O contents, due to evaporation; and 4) slopes of ~3 on a plot of δD vs. $\delta^{18}O$ values, indicating that most of the evaporation occurred in the vadose zone. The subsequent recharge and mixing of these irrigation waters into the pristine groundwater aquifer produces the correlations seen in Figures 2 and 3. This recharge process threatens the long-term groundwater resource for much of Yolo County, and may have serious short-term consequences for certain municipalities including Davis.

Secular Change of Nitrate. Municipal wells in Davis have experienced an overall increase in NO_3 concentrations from < 10 ppm in the 1960's to an average of 18 ppm today. Significant increases are also seen in all wells with sufficiently long temporal records, such as Well 12 (Fig. 4). Although there is a great deal of scatter in the data, the overall trend is a three fold increase over 30 years. Similar increases also occur in Wells 16, 18, and EM2 (not shown).

Some elementary calculations also point to agricultural activity and particularly fertilizers as the probable source of this nitrate. If it is assumed that the groundwater to a depth of 500 feet beneath Davis contains 18 ppm NO_3, and that the porosity of the rocks is 30%, then 7000 lbs (3200 kg) of nitrate reside in the groundwater under each acre of land. Probably 75% of this nitrate is anthropogenic. This amount is too large and the distribution too uniform to be accounted for by point sources such as barnyards or septic systems. At average fertilizer application rates, however, this quantity of nitrate would be applied to a cultivated acre in California in only 13 years. That is, according to Stephany et al. (1989), approximately 120 lbs of nitrogen (actual N), equivalent to 525 lbs of NO_3, are now annually applied on average to every cultivated acre in California. While this calculation is admittedly simplistic, it is probably no accident that the observed quantity of excess nitrate compares so closely with the amount of applied nitrate on a reasonable timescale.

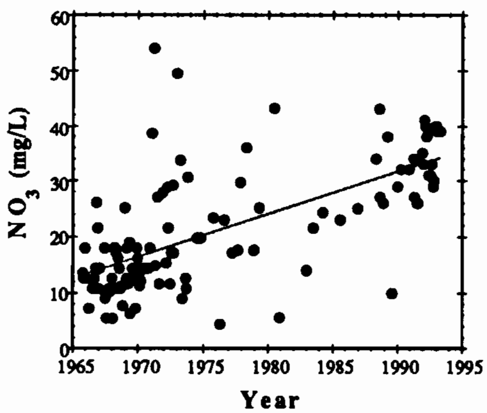

Figure 4. Nitrate concentrations in municipal well #12, City of Davis, show a clearcut increase over time. Data provided by the City of Davis Public Works Department.

DISCUSSION AND CONCLUSIONS

Isotopic data provide a powerful probe into the origin and migration of ground and surface waters and into the processes that affect them. Waters from the southern Sacramento Valley exhibit large isotopic variations that characterize their different sources. Examination of the spatial patterns of oxygen isotope ratios indicates that the hydrologic system in the valley has been profoundly affected by human activity.

Our data reinforce the conclusion of Davisson and Criss (1993) and Davisson et al. (1993 a,b), that pumping leads to the replacement of ancient, pristine groundwaters by younger surface waters. Because the surface waters are varied in origin, the examples of this process and the consequences also vary. In the Davis area, groundwater recharge is dominated by irrigation water, which can be identified by a number of different isotopic and chemical signatures. The induced replacement of ancient, pristine groundwater by younger, lower quality surface waters does not result in a permanent depression of the water table, but this process nevertheless represents a new type of groundwater "mining".

Insofar as groundwater recharge in many parts of the Central Valley is dominated by irrigation water, the recharge process will inevitably lead to increases in the concentrations of certain man-made chemicals and therefore to a decrease in water quality. The increasing trends of NO_3 contents commonly seen in Central Valley groundwaters strongly reinforce this conclusion. The continuation of current agricultural practices, and projected increases in groundwater demand, will aggravate this problem.

ACKNOWLEDGMENTS

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REFERENCES

Barnes, C.J. and Allison, G.B. (1983) The distribution of deuterium and ^{18}O in dry soils, 1. Theory. J. Hydrol., 60, 141-156.

Coleman, M.L., Sheperd, T.J., Durham, J.J., Rouse, J.E., and Moore, G.R. (1982) Reduction of water with zinc for hydrogen isotope analysis. Anal. Chem., v. 54, p. 993-995.

Craig, H. (1961 a) Isotopic variations in meteoric waters. Science, v. 133, p. 1702-1703.

Craig, H. (1961b) Standard for reporting concentrations of deuterium and oxygen-18 in natural waters. Science, v. 133, p. 1833-1834.

Davisson, M. L., Criss, R. E. and Campbell, K. R. (1993a) Preliminary report on the stable isotope imaging and characterization of surface and ground water resources in the southern Sacramento Valley. Lawrence Livermore National Laboratory, UCRL-ID-115393, 32 p.

Davisson, M.L., Criss, R.E., and Graham, M.M. (1993b) Sustainability of groundwater quality in intensively irrigated regions: Case example, Davis, California (invited abstract), 19th Biennial Groundwater Conference, Sacramento, CA, September 13 and 14, 1993.

Davisson, M.L. and Criss, R.E. (1993) Stable isotope imaging of a dynamic groundwater system in the southwestern Sacramento Valley, California, USA. J. Hydrol, 144, 213-246.

Department of Water Resources (1986) Elevation of Water in Wells, Spring, 1986, Sacramento Valley and Redding Basin. Prepared by the Central District and Northern District, Department of Water Resources, State of California

Epstein, S. and Mayeda, T.K. (1953) Variation of O^{18} content of waters from natural sources. Geochim. Cosmochim. Acta, v. 4, p. 213-224.

Ingraham, N.L. and Taylor, B.E. (1991) Light stable isotope systematics of large-scale hydrologic regimes in California and Nevada. Water Resources Research, 27, p. 77-90.

Sheppard, SMF (1986) Characterization and isotopic variations in natural waters. Rev. Mineral., v. 16, p. 165-183.

Spieker, A.M. (1984) California groundwater resources. U.S. Geol. Surv. Water-Sup. Pap. 2275, p. 147-152.

Stephany, P. W. and others (1989) Nitrate and Agriculture in California. California Department of Food and Agriculture, Nitrate Working Group, February, 1989, 66p.

Walker, F.W., Parrington, J.R., Feiner F. (1989) Nuclides and Isotopes. General Electric Co. Nuclear Energy Operations: San Jose, Calif., 57 pgs.

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California Department of Food and Agriculture

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The Fertilizer Research and Education Program (FREP) of the California Department of Food and Agriculture was created to advance the environmentally safe and agronomically sound use and handling of fertilizer materials. Most of FREP's current work is concerned specifically with nitrate contamination of groundwater.

The program facilitates and coordinates the development of research and demonstration projects by: (a) providing technical assistance and funding to carry out research, demonstration and education projects; (b) improving access of local entities to resources needed to carry out these projects; and (c) by developing information and serving as a clearinghouse of information required to conduct these activities.

The program serves growers, public agencies, agricultural supply and service organizations, extension personnel, resource conservation and irrigation districts, consultants, the general public and other interested parties.

PROGRAM HISTORY

In January of 1990 the Nitrate Management Program (NMP) was established by the Director of the California Department of Food and Agriculture (CDFA). Its objectives were to identify and prioritize nitrate sensitive areas throughout California and to develop research and demonstration projects to reduce agriculture's contribution to groundwater contamination from fertilizer use.

FREP first year activities concentrated on helping secure funding and technical expertise to start these research and demonstration projects. Initial projects were developed in the Salinas Valley and the Fall River Valley. The Salinas project is developing improved vegetable farming practices that reduce nitrate contamination while increasing the efficiency of fertilization and irrigation. The Fall River Valley project in Shasta County, selected as a pilot study, is assessing sources of nitrate contamination as well as developing best management practices for potatoes. The program name was changed to the Fertilizer Research and Education Program (FREP) in 1991 as a result of a broader mission.

COMPETITIVE GRANTS PROGRAM

In 1990 the Department was authorized to increase the mill tax on fertilizers to conduct research and education projects directed toward the environmentally safe and agronomically sound use and handling of fertilizer materials.

The review, selection, and funding recommendations for projects is done by the Research Subcommittee of the Fertilizer Inspection Advisory Board which includes growers, members of the fertilizer industry, state government and university scientists.

The program is currently supporting twenty two projects.

Research-oriented projects include nitrate reduction strategies in nuts and stone fruits, cool season vegetables, grapes and citrus. Studies on the development of updated guidelines for cotton nutrition, the impact of microbial processes on the efficient use of fertilizers, and an extensive literature review of site-specific crop management are also being undertaken.

Education-oriented projects include agricultural curricula development for primary and secondary schoolchildren, workshops and demonstrations on the evaluation and use of agricultural composts and two videos on best management practices. FREP is also supporting an agricultural laboratory sample exchange program and educational training for the Certified Crop Advisor (CCA) program. Staff assist in transferring the information generated by these projects to growers and interested parties.

MONITORING AND ASSESSMENT

The program's ongoing monitoring and assessment activities help refine priorities, improve access to information developed by other parties and support the program's education, outreach and public service activities.

These activities include participation in an inter-agency committee that coordinates efforts to reduce non point sources of contamination, participation in a University of California study team that is developing methods to assess the environmental and agronomic performance of various Best Management Practices, and membership in an advisory committee to the US Geological Service that is studying the extent and severity of nitrate contamination of groundwater in the San Joaquin Valley. Regulatory and legislative trends on nitrogen management across the country are also monitored.

FREP is also developing baseline information on fertilizer practices of target crops and exploring the use of Geographic Information Systems to pinpoint nitrate sensitive areas and help develop the most promising strategies for these areas. Additional activities include ongoing monitoring of scientific, technical, agricultural, industry, legal, government and policy developments and issues related to the program goals.

OUTREACH & PUBLIC SERVICE

FREP makes available a number of publications, conference proceedings, project reports, videos and reprints of articles on fertilizer, water, crop and soil management topics. FREP also has information on sources of funding for nitrate management projects, and can provide expert referrals for various fields.

FREP holds an annual conference, usually in the fall, where researchers and education specialists present their results from FREP sponsored projects. National and state perspectives on government programs and legislation dealing with nitrate in groundwater are also covered.

Program capabilities include a computerized system to store, process and produce resource materials and publications. The system, currently in its initial stages of implementation, will provide clientele with timely and accurate responses to their requests for information and referrals.

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OPTIMIZING NITROGEN MANAGEMENT IN VEGETABLE CROPPING SYSTEMS

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Growers of vegetable crops have historically used high N fertilization programs, with per crop application rates of 150-300 kg N/ha being typical. Since much of the vegetable acreage is double-cropped, annual N application rates commonly exceed 400 kg N/ha. Nitrogen removal with harvested product accounts for only a modest fraction of N applied, suggesting substantial opportunity for nitrate leaching losses. Historically, the low price of nitrogen relative to other production costs and high crop value provided vegetable growers little incentive to carefully tailor nitrogen fertility programs; current environmental concerns, and the threat of additional government regulation is finally sparking interest in using nitrogen fertilizers more efficiently.

In recent years, considerable study has been dedicated to documenting the nitrogen dynamics of vegetable cropping systems in California, particularly in the Central Coast production region. The following describes the main elements of efficient N management:

A. Utilize residual soil N.

Soil N cycling in vegetable cropping systems is generally quite rapid. Jackson and Warden (1993) and Pettygrove, et al., (1992) monitored mineral nitrogen levels in lettuce fields and found relatively large pools of mineral N despite conservative fertilization practices. R.F. Smith (San Benito County Farm Advisor, unpublished data) has monitored soil solution NO_3-N concentration in a number of vegetable fields and consistently found high values at the beginning of the cropping season, reflecting high soil residual NO_3-N.

There is strong evidence to suggest that mineralization of nitrogen from fresh crop residue and from more stable soil organic matter plays a significant role in the buildup and maintenance of this residual N pool. The previously cited sources all report substantial NO_3-N in surface soils at the beginning of the spring cropping season; residual NO_3-N from previous croping would have been expected to leach (or denitrify) with winter rains. Additionally, Jackson and Warden (1993) reported that soil nitrate levels increased approximately 9g NO_3-N/m^2 in the three-week period following incorporation of lettuce residue, equivalent to a net mineralization rate over 2 kg N/ha·day. A survey of fields in the Salinas/Hollister area showed that N mineralization rates between 1-2 kg N/ha·day were common; rates were highest following incorporation of fresh residue, but significant mineralization can occur throughout a cropping cycle (Hartz, unpublished data). Clearly, residual soil N and N mineralization potential should be considered in making fertility decisions.

B. Match nitrogen application to crop need.

Appropriate seasonal N rates for maximum productivity have been worked out for all major vegetable crops. These rates are generally modest, seldom exceeding 250 kg N/ha. However, many growers use substantially higher N applications for a variety of reasons. This not only contributes to NO_3-N leaching losses but can induce physiological disorders due to nutrient imbalances.

The timing of N applications can be equally important. The pattern of crop N uptake over the season has been documented for many important vegetable crops (Doerge, et al., 1991; Stivers and Jackson, 1992). Fruiting crops such as tomatoes, peppers and melons require relatively little N until flowering begins, then increase in N uptake, reaching a peak during fruit set and early fruit bulking period. As fruits mature, N need drops again. Non-fruiting crops like broccoli, celery and lettuce show slow N uptake through the first half of the season, with N need accelerating until just before harvest. Matching N applications to crop need by growth stage will maximize efficiency. It is particularly important to avoid heavy early season applications because the combination of low N demand and a poorly developed root system increase NO_3-N leaching potential.

C. Manage water efficiently.

Nitrate leaching requires two elements: soil NO_3-N and sufficient water to leach it out of the root zone. Consequently, efficient irrigation management can limit NO_3-N leaching losses during the cropping season. Upgrading conventional irrigation systems by laser leveling, shortening field length, use of surge values, etc., can dramatically improve irrigation uniformity. A well-designed and maintained drip irrigation system offers not only a high degree of uniformity but also the ability to apply water in small quantities to match actual crop need.

The nitrate leaching dynamics in drip-irrigated vegetable production has been studied under varying field conditions in California. In field trials on tomato and pepper over four seasons, soil solution from 0.8m depth was collected weekly by suction lysimetry and analyzed for NO_3-N content. An estimate of seasonal NO_3-N leaching was generated from these values and the estimated leaching volume. Additionally, anion resin traps (Hartz, 1992) were buried at 0.8m depth through the season to capture NO_3-N in leachate; the traps were recovered and extracted to provide another estimate of seasonal NO_3-N leaching loss.

A predictable pattern emerged from all tests. The NO_3-N content of soil solution at 0.8m declined as the season progressed despite continued N fertilizer application and leaching fractions as high as 30% of applied water. Early season values over 50 mg NO_3-N/liter were common; by the main fruit setting period, soil solution was consistently below 5 mg N/liter for tomato and 15 mg/liter for pepper. Clearly, once an extensive root system had developed and crop N demand was substantial, these crops (and presumably others) efficiently removed NO_3-N from soil solution; since the majority of seasonal water application occurred between fruit set and harvest, the net result was relatively little in-season NO_3-N leaching. Seasonal NO_3-N leaching estimates from both suction lysimetry and anion resin trapping were consistently below 30 kg/ha. These tests indicate that heavy early season N application would generally be an inefficient practice.

D. Monitor soil and crop N status.

Careful monitoring of soil and crop can fine-tune a nitrogen fertility program and help reduce or eliminate unnecessary N applications. Relatively high soil NO_3-N levels ($>$20 mg NO_3-N/kg in the top 30 cm) are commonly found in the first four to six weeks of the season in vegetable cropping systems, particularly where double-cropping is practiced. In such situations, N application can be delayed and/or reduced. A simple NO_3-N "quick test" technique has been developed to allow rapid on-farm soil nitrate determination (Hartz, 1994); this soil test procedure involves the extraction of nitrate through a simple volumetric dilution method, with NO_3-N concentration measured by colorometric test papers.

Plant tissue analysis is the most appropriate monitoring tool from mid-season to harvest. Conventional laboratory analysis of dried tissue is the most accurate technique, but petiole sap analysis with nitrate-selective electrode (Hartz, et al., 1994) is becoming more common.

E. Minimize fallow season leaching losses.

Most California vegetable fields lie fallow over the winter season, at risk of substantial NO_3-N leaching with winter rain. Crop residues are typically shredded and incorporated in the fall; with high fertility vegetable crops, these residues may be rapidly degraded, resulting in high soil NO_3-N levels. Our relatively mild winter climate allows mineralization to proceed rapidly through the fall and early winter. Overwintering NO_3-N leaching losses of over 150 kg/ ha have been measured in the Salinas area (Hartz, unpublished data), dwarfing typical in-season losses.

The use of winter cover crops is one approach to reducing NO_3-N leaching. Jackson, et al. (1993) have documented the ability of winter cover crops to reduce mineral N levels in soil, thereby reducing NO_3-N leaching potential. The use of cover crops may also have significant effects on soil tilth and fertility. Unfortunately, the difficulty of integrating cover crops into vegetable cropping systems, and the associated costs, have limited cover crop usage.

Few viable alternative practices are available. The use of nitrification inhibitors is not practical due to mild soil temperatures and regulatory concerns. Delaying incorporation of fall residues could reduce nitrogen mineralization substantially, but may also complicate spring tillage practices. At this point, the best defense against winter NO_3-N leaching is to limit overall N inputs into the cropping system.

LITERATURE CITED

1. Doerge, T.A., R.L. Roth and B.R. Gardner. 1991. Nitrogen management in Arizona. Arizona Cooperative Extension Publ. 191025.

2. Hartz, T.K. 1994. A quick test procedure for soil nitrate nitrogen. Comm. Soil Sci. Plant Anal. (in press).

3. Hartz, T.K. and W.L. Schrader. 1992. Optimizing drip irrigation management for improved water and nitrogen use efficiency. CDFA-FREP Ann. Report.

4. Hartz, T.K., R.F. Smith, K.F. Schulbach and M. LeStrange. 1994. On-farm monitoring of crop and soil nitrogen status. Calif. Agric. (in press).

5. Jackson, L.E. and B.T. Warden. 1993. Plant/soil nitrogen dynamics in a vegetable crop system. Proc. Calif. Plant Soil Conf., Jan. 25-26, Sacramento, CA.

6. Jackson, L.E., L.J. Wyland, J.A. Klein, R.F. Smith, W.E. Chaney and S.T. Koike. 1993. Winter cover crops can decrease soil nitrate, leaching potential. Calif. Agric. 47(5):12-15.

7. Pettygrove, G.S., B.R. Hanson, L.J. Schwankl, K.F. Schulbach, J.W. Inman, L.E. Jackson and R.F. Smith. 1992. Improvement of nitrogen management in vegetable cropping systems in the Salinas Valley and adjacent area. CDFA-FREP Ann. Report.

8. Stivers, L.J., L.E. Jackson and G.S. Pettygrove. 1993. Use of nitrogen by lettuce, celery, broccoli and cauliflower: a literature review. CDFA-FREP.

POMOLOGY NITRATE WORKING GROUP

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In March, 1992 at the Pomology Extension Continuing Conference, it was decided that nitrate pollution of groundwater is a serious problem affecting all pomologists. Consequently, we formed a cross-commodity working group to address this concern. Over the past year and a half, we have met several times and have established the following objectives:

1. Publish a manual on nitrogen fertilizer management covering general principles of good fertilizer and irrigation management for all major fruit and nut crops.

2. Hold a meeting to update farm advisors and specialists on nitrogen related research and techniques available for reducing nitrate pollution of groundwater.

3. Establish some type of cross-commodity demonstration and/or research plots which will help growers improve fertilizer management.

4. Coordinate individual nitrogen research projects being conducted throughout the state on pomological crops.

We have completed or made good progress on all four of these objectives. Our efforts during the next year will focus on objective one, the publication of a nitrogen fertilizer manual.

Profitability of Fly and Bottom Ash Use in Agriculture

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Fly and bottom ash from wood-fueled power plants is commingled and currently, much is being disposed of in landfills. In the near future, other sites will need to be sought because existing landfills are filling up and new ones are becoming harder to locate, landfill tipping fees are increasingly more expensive and there is growing interest in recycling this "low value resource" to return nutrients to the soil. Land application of ash is an effective alternative to disposing of the ash in landfills. This practice will require cooperation and coordination among at least three interest groups: 1) the power plant managers who have a constant supply of ash being produced, 2) the farmers/ranchers/forest landowners who want to improve the crop yield and soil quality from the nutrients added, and 3) air and water quality control and other resource agencies who want to protect soil, air and water quality. The objective of our field research has been to evaluate the crop growth, yield and quality response on rangeland pasture to several sources and rates of ash (fly and bottom) as compared to the response from fertilizer nutrient additions.

The same or similar treatments listed in Table 1 were randomly applied on the soil surface to plots 3 x 7.5 m (3 replications) to each of four rangeland sites utilizing one or two sources of ash. Physical and chemical characteristics of the five ash materials are given in Tables 2-3. Lawn mowers and hand shears were used to collect samples to measure forage yield and quality. The mowers used in 1992 to measure forage yield and quality introduced an unknown amount of ash dust, thus it is difficult to say if any responses beyond a seeming nitrogen increase in yield was observed (Figure 1 and Table 4). No significant differences between any treatments were observed in 1993 when the harvesting method was changed to cutting two-0.5 x 0.5 m areas with electric shears (Figure 2 and Table 5). The higher rate treatments (> 90 Mg/ha) all showed some degree of plant germination damage as the alkaline oxides were leached from the ash and accumulated in the surface 1 to 2 cm of soil. The addition of the second year application of ash seemed to be only slightly more detrimental than the first year application. Even with lower plant density, the forage yields were nearly the same or higher. At the Yuba site, considerably more annual legume density was observed in the ash and phosphorus treated plots. No consistent trends in the forage analysis were observed. This can perhaps be explained in part by the ash dust contamination in 1992, but it appears more likely that there were just no nutrient growth or quality responses in either year at any of the four sites. This is often the case when conducting research in California rangelands, particularly when rather fertile sites are unknowingly selected.

The most common beneficial characteristics of fly and bottom ash are its liming quality, and potassium and phosphorus content. The concentration of phosphorus and potassium as well as the calcium carbonate equivalent vary widely between the different wood-fueled power plants, and even from the same plant. Potassium content may be from 0.5 to over 10%, phosphorus from less than .1 to over 2% and calcium carbonate equivalent from less than 5 to 50% or more. The extremely wide range in concentrations call for several analyses before a grower or consultant can be assured of characterizing the material so that adequate application rates can be established. A word of caution is also in order at this point. Since many different materials can find there way into the wood fuel supplies of the power plants, it is necessary to check for certain undesirable elements, the most common of which is lead. Since much of the rangeland in California has acid soil, often responds to phosphorus and occasionally to potassium, the trials discussed earlier were established several years ago. Unfortunately, all were found to give few if any responses to either fertilizer (other than nitrogen) or ash nutrient additions. Yield responses to phosphorus and potassium are more common when annual legumes have been established and this trend was observed at one of the four sites. The other three sites have had a very low or no population of annual legumes from which a greater response might be expected.

At another field trial where a previously documented phosphorus and potassium response in alfalfa had been observed, ash was applied and the growth of a pea-wheat forage mix was measured. Slightly over a three ton per acre forage yield response was harvested where the ash was applied compared to the control where no fertilizers were applied.

The profitability of ash application to agricultural land is therefore highly dependent upon whether a crop yield response can be expected from the beneficial nutrients or liming capability of the ash. This is the same situation when any fertilizers and liming materials are used in agricultural production.

References:

Erich, M. S. 1991. Agronomic effectiveness of wood ash as a source of phosphorus and potassium. J. Environ. Qual. 20:576-581.

Erich, M. S. 1992. Phosphorus availability to corn from wood ash-amended soils. Water, Air, and Soil Pollution 64:475-485.

Etiegni, L., A. G. Campbell and R. L. Mahler. 1991. Evaluation of wood ash disposal on agricultural land. I. Potential as a soil additive and liming agent. Commun. in Soil Sci. Plant Anal. 22:243-256.

Ohno, T. 1992. Neutralization of soil acidity and release of phosphorus and potassium by wood ash. J. Environ. Qual. 21:433-438.

Table 1. **Fertilizer, Lime and Wood Ash Source Treatments**

Martin Ranch, Tuolumne County

	Nutrient Application, kg/ha				Mg/ha	
Treatments	N	P2O5	K2O	S	Lime	Ash
1. Control	0	0	0	0	0.	0
2. Am Nitrate	56	0	0	0	0.	0
3. Am Sulfate	56	0	0	64	0.	0
4. 0-45-0	0	56	0	0	0.	0
5. P + K	0	56	56	0	0.	0
6. P + K + S	0	56	56	28	0.	0
7. Lime	0	0	0	0	4.5	0
8. L+P+K+S	0	56	56	28	4.5	0
9. L+N+P+K+S	56	56	56	28	4.5	0
10. UltraPower	0	0	0	0	0	4.5 + 0.0
11. UltraPower	0	0	0	0	0	9.0 + 0.0
12. UltraPower	0	0	0	0	0	17.9 + 0.0
13. UltraPower	0	0	0	0	0	9.0 + 9.0
14. UltraPower	0	0	0	0	0	17.9 +17.9
15. Fibreboard	0	0	0	0	0	45.0 + 0.0
16. Fibreboard	0	0	0	0	0	90.0 + 0.0
17. Fibreboard	0	0	0	0	0	179.0 + 0.0
18. Fibreboard	0	0	0	0	0	90.0 +90.0
19. Fibreboard	0	0	0	0	0	179.0+179.0

Table 2. **Physical Characteristics of Ash**

Location	Type*	Moist	Bulk Density	Particle Size, mm < 1	1 - 2	2 - 5	> 5
County		g/kg	g/cc	g/kg	g/kg	g/kg	g/kg
Butte	B	395	0.49	305	152	136	407
Tuolumne	B	359	0.41	733	74	44	149
	G	78	1.05	729	36	43	192
Yuba	G	59	1.08	608	57	71	264
	Co	128	1.07	517	56	94	333

*Type of ash: B=high carbon, G=low carbon, Co=coal

Table 3. **Chemical Characteristics of Ash**

Concentration, g/kg

Location	Type*	N	P	K	Ca	Mg	S	Na	Cl
County									
Butte	B	1.67	1.4	53.7	78.9	7.3	1.9	1.1	3.2
Tuolumne	B	2.14	5.2	29.3	71.1	15.0	2.5	4.7	1.3
	G	0.40	5.1	29.7	69.7	14.9	9.4	8.8	1.7
Yuba	G	0.15	1.7	15.6	23.2	7.2	1.1	6.5	<.1
	Co	1.37	1.0	2.1	109.5	4.9	12.9	4.1	<.1

Chemical Characteristics of Ash

Concentration, mg/kg

Location	Type*	Zn	Cu	B	Mo	Ni	Pb	Cd	Cr
County									
Butte	B	51	41	64	<.05	7.4	0.5	<.05	1.0
Tuolumne	B	135	141	98	0.15	32.0	5.0	0.16	15.0
	G	833	404	164	4.79	41.9	226.0	2.82	81.0
Yuba	G	184	81	78	<.05	33.2	0.8	0.23	11.5
	Co	59	63	576	<.05	7.2	63.6	0.07	43.3

*Type of ash: B=high carbon, G=low carbon, Co=coal

Table 4. **Forage Nutrient Concentrations, April 23, 1992**

Martin Ranch, Tuolumne County

Nutrient Concentration, g/kg

Treatments		N	P	K	Ca	Zn	Cu	Se
1. Control	0	12.1	3.0	13.7	5.8	24	4.5	.05
2. Am Nitrate	N	11.1	2.9	14.1	4.6	17	4.2	.13
3. Am Sulfate	N+S	11.8	3.1	15.1	3.5	19	5.1	.08
4. 0-45-0	P	11.4	3.1	15.9	5.5	21	5.7	.05
5. P + K	P+K	12.1	2.9	15.6	4.6	21	4.5	.07
6. P + K + S	PKS	11.6	2.7	15.5	4.5	24	4.8	.08
7. Lime	Lime	11.1	2.8	17.3	4.9	20	4.2	.09
8. L+P+K+S	LPKS	11.9	3.0	13.4	4.8	18	5.1	.08
9. L+N+P+K+S	LNPKS	10.1	2.7	16.4	4.4	19	3.6	.11
10. UltraPower	4.5+0.0	11.3	2.9	14.9	5.1	21	4.2	.10
11. UltraPower	9.0+0.0	10.9	2.7	16.3	4.2	20	4.8	.10
12. UltraPower	17.9+0.0	9.9	2.7	15.3	4.8	22	5.7	.10
13. UltraPower	9.0+0.0	13.2	3.0	16.2	4.5	20	4.8	.07
14. UltraPower	17.9+0.0	12.6	2.9	18.3	5.6	24	6.6	.10
15. Fibreboard	45.0+0.0	11.6	3.1	15.2	5.2	24	7.8	.09
16. Fibreboard	90.0+0.0	10.1	3.2	21.9	4.3	19	6.9	.06
17. Fibreboard	179.0+0.0	9.1	2.7	20.1	4.8	17	7.8	.07
18. Fibreboard	90.0+0.0	9.6	3.0	20.6	5.0	19	8.4	.09
19. Fibreboard	179.0+0.0	9.8	3.1	19.5	6.2	20	9.9	.08

Table 5. **Forage Nutrient Concentrations, April 20, 1993**

Martin Ranch, Tuolumne County

Nutrient Concentration, g/kg

Treatments		N	P	K	Ca	S	Zn	Cu	Se
1. Control	0	13.7	3.8	23.8	4.1	1433	20	5.1	.01
2. Am Nitrate	N	14.8	4.0	24.7	6.1	1353	22	5.9	.03
3. Am Sulfate	N+S	15.5	3.9	27.2	5.3	1587	24	5.4	.03
4. 0-45-0	P	14.5	3.8	22.1	3.7	1390	19	5.3	.02
5. P + K	P+K	15.2	3.7	23.8	4.8	1367	24	5.6	.04
6. P + K + S	PKS	14.9	4.0	24.4	4.1	1727	24	5.4	.01
7. Lime	Lime	15.2	3.9	26.0	4.2	1573	22	5.3	.02
8. L+P+K+S	LPKS	14.7	3.8	25.0	3.7	1493	21	5.3	.02
9. L+N+P+K+S	LNPKS	14.6	4.2	27.1	5.0	1563	22	5.0	.02
10. UltraPower	4.5+ 0.0	14.6	3.9	25.8	4.7	1663	22	5.6	.02
11. UltraPower	9.0+ 0.0	15.1	4.0	25.6	4.5	1787	29	5.6	.02
12. UltraPower	17.9+ 0.0	15.6	4.2	26.6	4.6	2093	22	5.6	.04
13. UltraPower	9.0+ 9.0	15.2	4.1	26.2	5.3	1850	21	5.1	.04
14. UltraPower	17.9+ 17.9	15.3	3.9	24.4	4.4	2170	24	5.5	.03
15. Fibreboard	45.0+ 0.0	15.4	4.2	25.3	4.7	1677	24	5.9	.03
16. Fibreboard	90.0+ 0.0	14.2	4.0	23.9	4.5	1817	18	4.8	.02
17. Fibreboard	179.0+ 0.0	13.6	4.0	25.0	4.4	1940	21	4.8	.02
18. Fibreboard	90.0+ 90.0	14.6	4.1	26.5	4.2	1850	23	4.7	.02
19. Fibreboard	179.0+179.0	13.6	4.1	25.4	3.4	2033	20	4.7	.02

Figure 1. **Rangeland Forage Yields - April 23, 1992**
Martin Ranch, Toulumne County

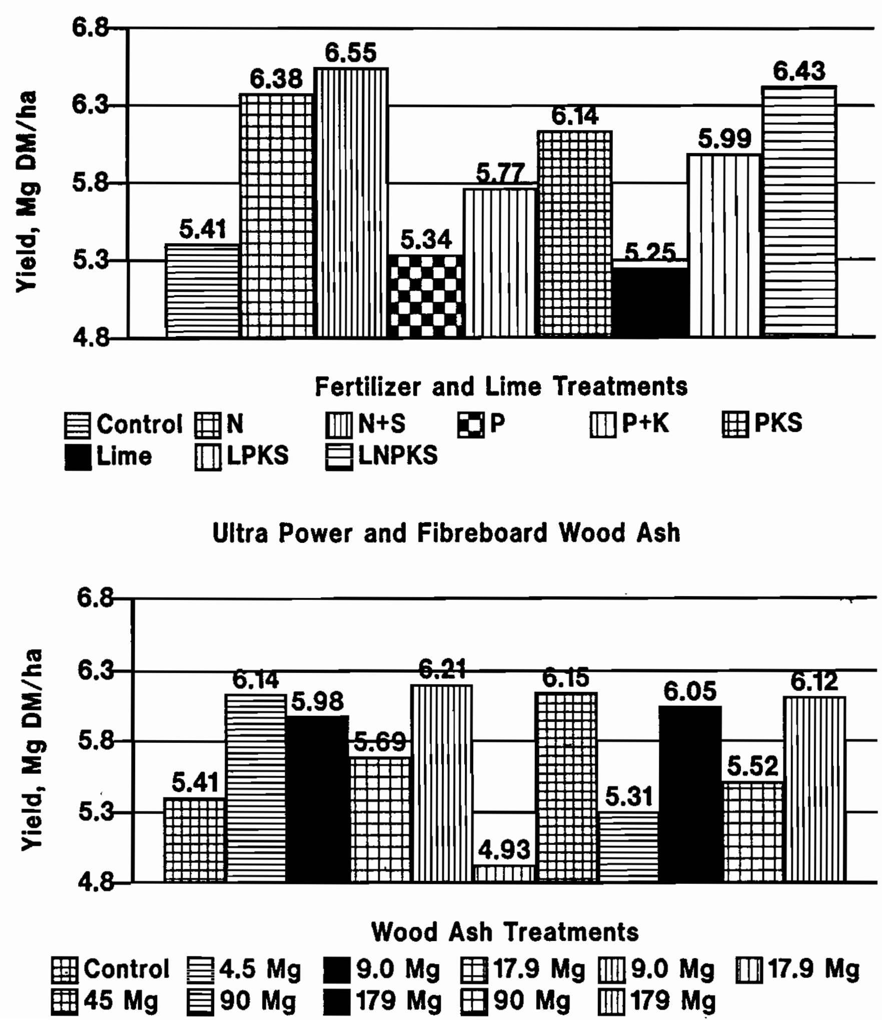
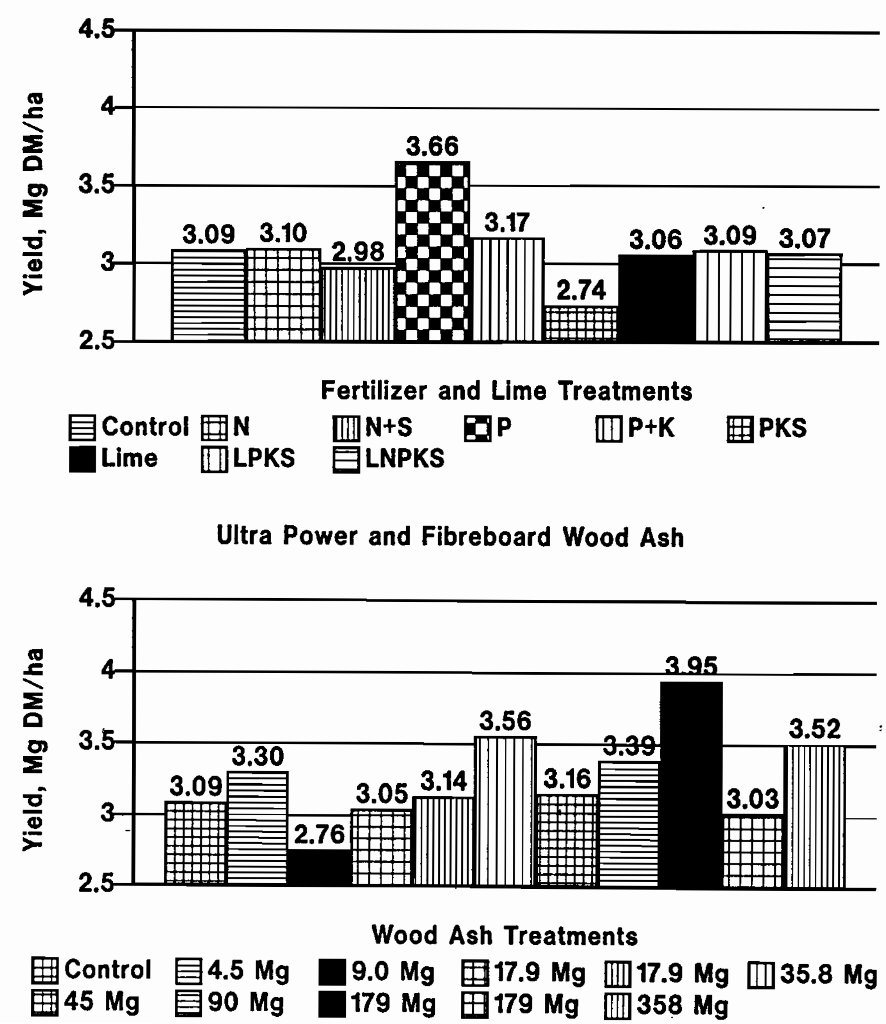


Figure 2. **Rangeland Forage Yields - April 20, 1993**
Martin Ranch, Toulumne County



ENVIRONMENTAL POLICY AND THE DAIRY INDUSTRY:
Situation, Consequences and Options

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Use of the state's natural resources to support a large and growing population, serving the needs of agriculture, while protecting environments is a difficult, and often contentious, process. Economic demands and opportunities have encouraged dairy agriculture in California to grow and capitalize on economies of size, while enjoying the comparative advantages of the states climatic, natural and agricultural resources.

As the general public has distanced itself from its farm roots, its attitude has rapidly changed from one of agrarian sympathy and understanding to one of scrutiny and criticism. It has become especially critical of any agricultural practices perceived as deleterious to the environment. Given the urgency of many environmental issues and the increasing involvement of the public, it is not surprising that the highly visible dairy industry in the West has attracted attention.

The necessity of compliance with environmental regulations threatens to make the state's dairies and processors more costly to operate, perhaps dulling their competitive edge. On the other hand, there could also be opportunities such as treating manure as a valuable resource rather than a nuisance. The dairy industry has no choice but to take a proactive stance toward a host of environmental issues. Positive responses range from packaging in recyclable containers to improving dairy waste management practices and finding new, commercial uses for manure.

Dairy Waste Management

Although California dairy producers have long enjoyed a cost advantage over their eastern and midwestern counterparts, increasingly stringent environmental regulations may significantly raise costs of production in the state. Policies are in place, and are being added, to protect the state's water, air, and other natural resources, and it is unlikely that the industry will receive any help from the state or federal governments with the increased costs of compliance. Nor is it likely that the public will support any special dispensation to the industry to mitigate these increased costs. On the contrary, more environmental "strings" will probably be attached to federal and state dairy programs, requiring costly compliance by program beneficiaries.

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Water Quality

In the past, dairy designs recommended that corrals slope away from the milk barn, preferably towards the nearest stream or ditch. That way, when it rained, the milk barn would stay dry while the storm would wash the manure out of corrals and off the property. An article from the 1950s states that "many of the original dairy sites were selected to facilitate movement of excess runoff and wastewaters from the barn areas directly to natural channels and drainage ditches." It is only relatively recently that the environmental effects of improper wastewater disposal have been understood so regulations and controls can begin to be formulated and construction and management practices improved.

In 1970, California passed the Porter Cologne Water Quality Control Act, stricter than, but serving as a model for, the federal Clean Water Act of 1972. The State Water Resources Control Board implements California's water quality law, dividing the state into nine geographical regions, each with its own governing board and basin plan. The number of dairy cattle by region is shown in Table 1. (Two of the nine water quality regions in California do not have any dairying)

Table 1. Number of Dairy Cattle by California Water Quality Control Regions, 1991

Region	# dairy cattle
North Coast	34,200
San Francisco Bay	40,800
Central Coast	7,600
North Central Valley	49,000
South Central Valley	694,000
Santa Ana	308,000
San Diego	13,500

Source: Bennett and Butler, "Environmental Policy and the Dairy Industry: Situation, Consequences, and Options." Forthcoming

Southern California's Chino Valley at the headwaters of the Santa Ana River, was the largest dairy region in the United States between 1965 and 1975. But largely due to nitrate salt contamination of the aquifer, the drinking water source for the people of Orange County, the regional board set down regulations that prohibit any further disposal of animal wastes on land. Now, nearly all cattle manure must be transported outside of the water shed, and many dairy farmers are following - that is, they are moving their operations to the Central Valley.

The state's dairy industry has recently become concentrated in the San Joaquin Valley from San Joaquin County through Kern County where 694,000 mature dairy cattle are kept on some 1,400 operations (Table 1). There is considerable concern here too about degradation of ground water and the quality of the surface water that drains into the San Joaquin River Delta. Currently, south valley rules require that dairy producers own sufficient acreage to handle waste entirely on the dairy property (4 animal units per acre).

The State Water Resources Control Board held three years of hearings in the late 1980s on the water quality of the Delta and the salt water estuaries of the San Francisco Bay. The size and rapid growth of the south valley's dairies have piqued the concern of debate participants and many others as well. Municipal interests and environmentalists argued strongly for tighter controls on agricultural drainage. The result is more regulation and controls on dairy operations as both a point and nonpoint source of pollution.

Point Source Control

In the 1970s, under Porter Cologne, California became subject to point source pollution restrictions and controls - a point source is a fixed location where waste material is stored or accumulated and may be conveyed into a receiving water. In the early years of the law, the overextended regional boards tended to focus on chemical storage problems. But in the late 1980s, dairy farms and their waste management systems, clearly a potential point source of pollution, became a top priority.

Point source controls now affect the collection, storage, and disposal of dairy wastes. While enforcement varies by region, in general, regulations require that all waste either be conveyed off the site or be contained on site in a manner that will not allow nutrients, minerals, or other substances to migrate to groundwater. All manured areas, walkways, alleys, milk barns, feeding areas, and corrals are to be designed and managed to convey all waste material to a holding area. The waste in the holding area may be solid or, more often, liquid with mixed solids from flushing the concrete areas. The holding area must be properly constructed and of sufficient capacity to withstand the heaviest rain (for existing dairies, a 25-year, 24-hour rain; for new ones, a 100 year peak storm flow). Wells to monitor the holding areas may be required. Producers must report to the state about the size and capacity of their waste management system.

Nonpoint Source Controls

Nonpoint source pollutants include various materials from storm runoff, excessive soil sediment, and nutrients/chemicals from agricultural lands. The "nonpoint" means that sites are not readily identifiable at discrete locations - no one can "point" a finger precisely at the source.

The water quality control regions have basin plans with nonpoint source pollution regulations, including controls on spreading dairy waste on farmland. Allowable rates of manure application are specified, depending on the conditions of the site. However, specific programs, such as nutrient budgeting and waste and soil nutrient monitoring have not yet been developed by any of the regional boards.

It is very important that dairy operations have sufficient farmland relatively nearby to spread the manure or manure-water - either on their own pasture or on other farmers' crops. The lack of sufficient area is one of the major problems in the Chino Valley as the area urbanizes. But even when there is sufficient area, application rates will continue to be more carefully scrutinized for potential and actual leaching to groundwater. If hazards are detected, controls will sooner or later be imposed.

Other Regulations

The federal Coastal Zone Management Act and Reauthorization Amendment, passed in 1990, aims to reduce nonpoint source pollution into estuaries, bays, and the ocean. The objectives of the act are translated by state agencies into specific regulations. Best Management Practices are recommended for a variety of land uses, including dairy. Research, education, demonstration projects, and the like have been instituted, but so far only voluntary compliance has been solicited. There could eventually be profound implications for California's dairies, for some state agencies argue that the boundary of control should be at the crest of the Sierra.

The oldest state water-protection policy is the Fish and Game Code 5650, to protect the state's waterways and natural fishery resources. The regulation prohibits any discharge that would adversely affect fish and aquatic life. For a long time, penalties were low, but a recent amendment raised the fine from $2,000 to $25,000 and made the burden of proof easier to establish. Some dairy farms have been prosecuted under this law.

Consequences of Environmental Policy

According to the California Department of Food and Agriculture (CDFA), there are approximately 1.2 million mature dairy cattle in California. (There is also approximately another 1 million young dairy stock, and about 1 million beef cattle). The distribution of dairy cattle by water quality region is given in Table 1. The wastes generated from California's dairy cow population (as estimated from American Society of Agricultural Engineers data and extrapolated within the water quality regions as depicted in Table 1) ranges from 1.6 million pounds per day in the San Diego region to over 89 million pounds per day in the Central Valley region.

In order to effectively reuse or recycle manure nutrients back into the soil as fertilizer for crop production, farm land access is, and will be, essential. Based on nitrogen availability and application,and assuming nitrogen losses during manure storage and handling of 25% to 75%, between 42 and 128 million pounds of nitrogen will be available each year in the San Joaquin Valley alone. The acerage required for the least demanding situation (75% nitrogen loss and 100 pound per acre per year) in the San Joaquin Valley is approximately 400,000 acres. In the worst case scenario (25% nitrogen loss and 50 pounds per acre per year), the land required exceeds 2.5 million acres. In either case, the acerage required to recycle these nutrients exceeds the land currently available to dairy producers to apply the manure generated by their cows.

Proctive Options for the Dairy Industry

On the plus side, manure is an important source of nitrogen, phosphorus, potassium, and other minerals. Crop farmers want it and are willing to pay for it to use as a soil conditioner and soil quality enhancer.

Particularly in the south valley, commercial composting and bagging firms purchase tractor-stacked, dried manure that they compost, process, bag, and sell as fertilizer or a soil amendment. In processing they remove weed seeds and minerals and incorporate additives. The economic feasibility of the enterprise depends importantly on transportation costs and demand for the final product. The problem in southern California is that the manure supply exceeds demand for the product, while hauling distances are considerable. There, instead of having to purchase manure to process, the companies are paid to haul it away.

Expansion of the current composting/bagging industry is one option to ameliorate the waste disposal problem. Product promotion to local nurseries and the general public could help on the demand side. The activity might be subsidized by assessments on an area's producers or the producers could form a cooperative to run and manage a composting/bagging business.

Manure is also potentially an important energy source, depending on the relative costs of alternative sources. There are at least four methods of feasibly producing energy from dairy waste:

- Anaerobic digestion (bacterial fermentation in the absence of oxygen) produces a combustible gas (biogas) that is about 60% methane, 40% CO_2, with trace amounts of water and SO_2. The gas is used in an internal combustion engine to drive an electric generator. Waste heat can be used in the fermentation process, while digested solids and liquids can be sold as compost or fertilizer. Although the mass reduction is only about 2%, the digested effluent is much more stable, marketable (it doesn't smell), and environmentally acceptable. On a typical on-farm system, revenues should cover the operating costs of $3-$5 per wet ton of manure processed.
- Direct combustion of completely dried manure produces heat to make high pressure steam that in turn powers an electric generator. The low-pressure steam/condensate may also serve as a

heat source for other applications. However, the high ash content of the manure can cause problems, and, without expensive emission control systems, the burning may not meet air quality control standards.

- Gasification is similar to direct combustion in that manure is burned, but the combustion occurs in an oxygen-starved environment. A low-Btu, hot combustible gas is formed that can be used for a variety of purposes, including heat. However the energy conversion is not quite as good as it is in direct combustion, and air pollution controls are necessary.
- Ethanol fuel and other industrial chemicals can be produced from manure by converting manure biogas first to sugars (using acid, organic solvent, or enzymatic hydrolysis). The sugars undergo ethanol fermentation, and the "beer" is distilled. Although this process is still very much in the development stage, it results in high manure mass reduction with minimal environmental impact. Ethanol yields from manure could range from 30 to 80 gallons per dry ton. Production costs, based on manure at a zero price, are estimated at $.50 to $1.00 per gallon.

Manure can also be processed for a variety of uses. Two examples include densification and processed animal feeds:

- Densification is a process that compresses raw or dried manure into logs, cubes, or pellets. Any of the various systems mechanically subject the biomass to high pressures and temperatures that result in the material binding to itself (though some systems require a binding agent). The material is then pressed through a die and cut at regular intervals. The products can be marketed as fertilizer, fuel, or even feed. The simplest process is fuel (for direct combustion or gasification). Average production costs, including equipment, run $15-$20 per ton of dried manure, but producing high-valued fertilizer or feed can easily double these costs. Densification opens the possibility of manure exports.
- Animal feeds can be made from processed manure. Dairy manure retains some of the value of the original feed, making recycling it for feed at least a possibility. Because of high salt levels and potential hazards from residual antibiotics, and pathogens, great care must be taken in processing manure as feed for dairy or any other animals. Currently, feeding processed dairy manure to milk cows is not legal. "Wastelage," an ensiled mixture of manure and hay, has been successfully fed. Another strategy is to pelletize (or cube) manure with feed grains and molasses as a feed for range cattle, thus effectuating vast dispersal of the original manure.

Local County/Regional Level Options

At the local county or regional level, there appears to be a need for local animal waste committees. An Animal Waste Committee was formed in the mid-1970's in the Sonoma-Marin region to assist producers and agencies implement the point source control regulations of Porter-Cologne. The committee was reactivated in 1988 to attend to the newer water quality issues. The committee is comprised of members of several regulatory agencies, dairy producers, Farm Bureau, Soil Conservation Service, interested businesses and academics, including University of California Cooperative Extension staff.

The committee meets on a regular basis to discuss specific issues and to plan educational efforts. Educational programs include special nesletters, workshops, seminars, and tours. The committee serves as an open forum for the discussion of regulatory programs, educational programs, and the primary response to specific complaint issues.

State Level Options

There are two activities that dairy producers could be involoved in at the state level. The first is the formation of a Dairy Waste Coordination Task Force that is charged with the responsibilty of communicating and participating in the co-ordination of all regulatory requirements for the dairy industry.

The second is the implementation of a Dairy Waste Facilities Upgrade Trust Fund to provide a source of funds to assist the dairy industry meet the challenge of the water quality agenda.

Federal Level Options

Finally, the dairy industry could be active at the federal level by lobbying for focused policies that enhance the attainment of resource conservation and environmental protection. Producers do not intentionally pollute or degrade the environment, but the production methods that they have been encouraged to use in order to increase the efficiency of U.S. agriculture are now often responsible for the environmental degradation that has occurred. It is necessary, therefore, that agricultural policy be used to encourage producers to benefit from resource conservation and environmental protection. There are limits to the sacrifices that individual producers are willing or able to make in order to achieve a more environmentally sustainable agriculture. Therefore, some of the resources currently used to encourage increased efficiency in agriculture should be diverted to programs that encourage longer term targets of resource conservation and environmental protection.

MECHANICS OF MARKETING, MOVING

AND APPLYING SLUDGE

WITH GROWER RESPONSE

PRESENTED BY:

JIM BRISCO

BRISCO ENTERPRISES

A GENERAL ENGINEERING CONTRACTOR

In California, there are nearly 800 wastewater treatment facilities. The majority of these treatment facilities have a by-product of bio-solids (sludge) which is sadly misunderstood and under-utilized. With a better understanding of bio-solids, municipalities and the agricultural industry can arrive at a point of beneficial reuse.

To begin, a point must be made regarding bio-solids. All wastewater treatment facilities are unique as they relate to the waste stream being treated by the plant. Therefore, the bio-solids are similarly unique.

Many factors contribute to this:

The amount and type of industrial waste; industrial waste inspection; the amount or percentage of domestic waste; the age and technology being used in the treatment facility; and the competence of the personnel operating the facility.

Factors contributing to the make-up of the bio-solids are varied and diligent care must be taken in the use and application of the bio-solids. If properly carried out, bio-solids can be a great benefit to our agricultural industry.

The project which is the subject of this presentation is the City of Modesto Beneficial Reuse of Bio-solids. The contract was awarded to Brisco Enteprises in February, 1993. This contract was noticed in December, 1992, and the contract required the selected contractor to accomplish the following:

1. Provide permits necessary for the beneficial reuse of bio-solids.
2. Provide land-use agreements with property owners on whose land the bio-solids would be applied.
3. Remove from the wastewater facility nearly 23,000 cubic yards of bio-solids, process and treat as necessary.

The first order of work was to secure certified laboratory analysis of the Modesto bio-solids. Extensive laboratory analysis is required of the Modesto facility by the Regional Water Quality Control Board. The analysis was completed and reviewed for heavy metals and other objectionable constituents. Heavy metals were found to be very low and pH was at an acceptable level. Even though extensive sampling results were available, additional sampling was accomplished prior to bidding this project. This additional sampling helped to insure that the bio-solids would not only be a soil ammendment but that the consitutent levels could be of beneficial use.

The second order of work prior to bidding this project was to locate agricultural operations within the community that would be willing to utilize the bio-solids. Many organized corporate operations declined to use the bio-solids for fear their competition would use this information as a negative advertising tool. Many attempts were made to approach co-operatives and small agricultural associations, however, very few positive responses were received. It is important to note that at about this time two very negative articles were published in two of the farming trade magazines. These articles dealing with another state and perhaps including inaccurate data, had a quite negative impact on the potential reuse of bio-solids. Also, a demonstration project of bio-solids reuse in the same county was flooded by heavy winter rains generating negative press in the local news media.

The next approach was to meet one-on-one with the farmers in the area to educate them on the beneficial aspects of reuse. We provided extensive laboratory reports and information for their consideration.

Our approach has been, and continues to be, that the end-user should not be responsible for any costs associated with the reuse program. Our firm provides trucking, spreading and incorporation into the soil. The time-table is closely coordinated with the farmers. Areas to be utilized are sampled for metals and total nitrogen prior to application of the bio-solids as well as after crop harvest. The sample results become part of the permanent record. Generally, agronomic rates are discussed based on nitrogen availability and this becomes the basis for application rates of the bio-solids.

The marketing of bio-solids has been difficult, at best, even with all of the cost being borne by the contractor. By and large, the users have been knowledgeable, educated small argri-business who rely on the best scientific data for information.

The bidding process is a lengthy one. Consideration for the permit process, sampling and monitoring and the cost for producing the environmental documents were in addition to the normal estimating process. The acutal estimating for processing, screening, transporting and incorporating was the most routine task of the bidding process.

Following the award of contract for the beneficial reuse of bio-solids, we proceeded to work with staff on the environmental document (CEQA), including working with the city's Environmental Assessment Committee. Six months later with more stringent requirements than the EPA's 503 regulations, we submitted a permit request along with the negative declaration to the Central Valley Regional Water Quality Control Board. Approval was expected by January, 1994.

In September, 1993, we made a request on behalf of the City of Modesto that the regional board allow application of bio-solids to city-owned agricultural land used as a wastewater disposal site. This request stated that the bio-solids drying beds at the plant were full, some 12,000 cubic yards, and the City had an immediate need to empty the drying beds to allow for winter/spring bio-solids storage.

The request was granted, allowing up to 10,000 cubic yards to be utilized on winter oats and salvage corn. The bio-solids from the drying beds were screened prior to this time and were ready for transport to the disposal site. Loading and transporting of approximately 8,000 cubic yards was accomplished within a week's time. Concurrently, the spreading and discing operations were carried out.

The majority of the time was spent procuring permits for this project. Of course, the removal of the bio-solids will be ongoing for some time, largely dependent upon crop rotation. While we know that regulation is an important part of the equation, a trend toward over-regulation will cost municipalities considerable time and money. This will ultimately affect agri-business due to higher costs in wastewater treatment. Overall economic advantage will most certainly be realized by all who would consider the beneficial reuse of biosolids.

Impacts of Sewage Sludge on Soil Physical Properties and Nitrogen Availability

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Introduction

In 1975, a sewage sludge land application experiment was initiated at the Moreno Field Station, University of California near Riverside, California. In this experiment, one composted sludge and two anaerobically digested liquid sludges from the Los Angeles metropolitan area were applied annually on replicated experimental plots at various rates from 1975 through 1981. Following the application, sludges were incorporated and crops were planted. During the course of the experiment, samples of the sludge-receiving soils and harvested plants were collected and analyzed to determine the impact of sewage sludge application on physical and chemical properties of soils and on crop yields and quality. This presentation utilizes the data from the experiment to analyze the effect of sewage sludge application on physical properties of soils and the availability of the sludge-borne nitrogen.

Physical Properties of Sludge-treated Soils

The physical properties of the soils were measured in terms of the soil's (1) bulk density, (2) hydraulic conductivity, (3) water holding capacity, and (4) modulus of rupture. Results indicated the agronomic nature of the soil may be improved by the addition of sewage sludge. The data showed that sewage sludge applications result in reduction of soil bulk density, and cohesion, and increase in water holding capacity and hydraulic conductivity. The improvements, however, were limited to the soil layer where the sludge was incorporated and the amount of sludge required to produce a significant change in soil properties is greater than the amount normally used to satisfy nitrogen requirements for crop growth.

Availability of Sludge-borne Nitrogen

Based on the field-derived nitrogen balance, the mineralization rates of liquid sludge and composted sludge were 85, 7.5, 2.5 and 2.5% and 45, 22.5, 10, and 10%, respectively for the first four years following incorporation of the sludge. These rates are considerably higher than those determined by field experiments conducted in other parts of the country. The soil texture did not affect the rate of mineralization. Assuming the N mineralization is a first-order reaction, the amount of sludge required to satisfy the crop nitrogen requirement may be calculated. Nitrogen inputs exceeding the N requirements for crop growth resulted in leaching and accumulation of nitrate in the soil profile. The rate of nitrate accumulation (in the soil profile) with respect to cumulative N input is the same for composted and liquid sludges.

ENVIRONMENTAL ISSUES ASSOCIATED WITH LAND APPLICATION OF MUNICIPAL WASTES

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Municipal wastes that have been considered for land application include residuals from wastewater treatment (sewage sludges), composted garbage, yard trimmings, incinerator ashes, and organic industrial or food processing wastes. These materials contribute valuable organic matter and/or nutrients to the soil, but they are also associated with various demonstrated or potential environmental risks.

Human activities generate municipal wastes with a variety of organic, inorganic, and biological components. Applied to land, the presence of these compounds may or may not be cause for concern, depending upon (1) the nature and concentration of potential pollutants within the applied material, (2) how much material is applied, (3) the relative mobility of the pollutant, (4) its persistence in the environment, (5) the inherent toxicity of the material and (6) the degree of acceptable risk associated with the affected population. Humans, livestock animals, wildlife, and plants (either the crop or plants in the natural ecosystems) may encounter pollutants in the soil, in air, in surface waters, or in groundwaters. Some contaminants, such as phosphorus, may be of concern in some environments but either do not adversely effect or are absent from others. Other contaminants, such as pathogenic microorganisms, may contaminate soil, water, and air.

Table 1 indicates areas of potential concern when municipal wastes are applied to land. For example, metals in municipal wastes tend to be of concern as soil contaminants; most are relatively immobile and transport to groundwaters is minimal. High concentrations of metals can elicit toxic effects in humans, livestock, wildlife, and plants. The table does not indicate the degree of risk faced by a population. Such an assessment would require information as to the specific exposed species, the contaminant involved and its concentration over time. With more information, it is often possible to identify contaminants that limit short- and long-term application rates.

Table 1. Areas of observed and potential risk for selected contaminants in municipal wastes

Medium	Issue	Humans	Livestock	Wildlife	Plants
Soil					
	metal	☒	☒	☒	☒
	pesticides				☒
	pathogens	☒	☒	☒	☒
	salts				☒
Groundwater					
	viruses	☒			
	nitrates	☒			
	selenium				
Surface Water					
	pathogens	☒	☒	☒	
	natural organic material (NOM)	☒			
	phosphorus			☒	
	biochemical oxygen demand (BOD)			☒	
	selenium			☒	
	trace organics	☒			
Air					
	aerosols	☒			
	odors	☒			
	nutrient deposition				☒

STATE REGULATION OF AGRICULTURAL USE OF MUNICIPAL SLUDGE

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Regional Water Quality Control Board, Central Valley Region

Since the Administrator of the U.S. Environmental Protection Agency signed the federal *Standards for Use or Disposal of Sewage Sludge* (40 CFR Part 503, or "503") in November 1992 there has been much speculation on whether the state's role in and criteria for sludge regulation would diminish or increase. A year later, this question still remains, but the State has rejected primacy for the 503 program itself. The Regional Board will determine in December whether it will withdraw from sludge regulation completely. The agricultural community that uses sludge will be affected by the decision not to accept the program and those decisions yet to come. Depending on a sludge users individual circumstances, the effect may be good or bad.

When the State Water Resources Control Board and the California Integrated Waste Management Board decided not to seek authorization to administer the 503 program in California, the primary reason was resources. To administer the program takes a major commitment in staffing and funding. Neither agency has the money to take on a major new program at this time and the state feels EPA has not offered enough money to cover the increased program costs. Negotiations between US EPA and the State are continuing, so it is possible the State could still wind up administering the program. If the State decided today to take the program, however, California would probably not have authorization for a couple of years. The negotiations between EPA and the State for the NPDES and RCRA programs each took years. State laws and regulations would have to be changed to equal or exceed the 503 regulations and procedural problems related to implementing the program would have to be worked out.

Although the State may not be taking over implementation of the 503 regulations, we are not ignoring them. Regional Boards in Santa Rosa, Oakland, and San Luis Obispo, plus the Central Valley Region, regulate areas where most biosolids will be discharged. All the

Regions are doing about the same thing. WDRs are issued for Class B sludge reuse projects. WDRs currently being issued are a melding of traditional WDRs and the 503 regulations. These previously were based on the older 257 regulations and the Department of Health Services *Manual of Good Practice for Landspreading of Sewage Sludge*.

However, the Boards are not necessarily accepting the 503 regulations as the last word in regulation. For a variety of reasons, including public concerns, local conditions, good and bad experiences with past sludge application projects, and "tradition", the Boards are often adopting more stringent regulations.

Compliance with the WDRs do not guarantee compliance with the 503 regulations. For many projects, EPA requires reporting which must be submitted to EPA. Submitting reports to the Regional Board would not count for 503 compliance. The 503s go into some operational and reporting details not normally specified in WDRs, so the WDRs may omit some compliance items necessary for 503 compliance.

Prior to the 503s, the WDRs loosely followed the old 257 regulations, using the metals limitations and disinfection standards in the federal regulations and state guidelines, but adding setbacks, nuisance controls, and other matters of local concern. The details of what the Regional Board added depended greatly on experience with biosolids projects. If biosolids got washed into a stream following a rainstorm on one project, the next project to apply for WDRs likely got strengthened provisions to contain runoff. Protests over biosolids projects tend to also add restrictions, as the boards try to lessen the concerns of the neighbors and general public. Once restrictions are placed in one set of WDRs, they tend to pass on to other WDRs. This is in part due to the conservative nature of the regulatory process. But it is also, in part, due to project opposition. If the last WDRs had a 100 foot setback from the river, the new WDRs had better have at least a 100 foot setback, or neighbors complain about unfair treatment and increased threat to their health. It can be hard to keep the regulatory process free from emotional arguments for contested projects. The public has very real concerns about biosolids use, whether or not these concerns have technical merit. The public's concerns are real and the Boards do listen to them.

With the advent of the 503 regulations, changes in the WDRs are taking place. The new metals limitations and disinfection standards are being used. Where the 503s are more stringent than WDRs have been, the WDRs are incorporating the federal limits. For the most part, the "extras" that the Regional Boards have been adding over the years are still being adopted in the new WDRs.

One relatively new area of biosolids regulation involves Class A biosolids. There have been a few projects for many years which produced composts containing biosolids for distribution to the public. The projects in California were primarily monitored by the California Department of Health Services, with little involvement by the Regional board. DHS dropped out of the biosolids picture a few years back and the Regional Boards have begun to look at the composting operations. The 503s have given a strong push for moving biosolids away from the treatment plants. Part of that push has translated into increased interest in production and distribution of Class A biosolids for a variety of uses. The State and Regional Boards are looking at regulation of Class A biosolids. While within jurisdiction, it is certainly possible that the water quality risks associated with use of Class A, low metals biosolids are low enough that Boards will decide to waive WDRs or otherwise limit our involvement.

There is also debate on how much, if any, regulation the Boards should provide for Class B biosolids usage. Some feel that the federal regulations are adequately protective of water quality, public health, wildlife, etc., and that no further regulation by the State is needed. Others feel that federal regulations are minimum standards and not necessarily fully protective. They believe the State should provide additional regulations, as California often does, to supplement the federal regulations.

Advantages of Regional Board regulation of use of biosolids are problem avoidance, guidance, and public confidence.

Disadvantages to Regional Board involvement in biosolids are duplicate, potential delays, and potential regulations.

GENERAL PERMIT

In an effort to speed up the permitting process for biosolids projects and to reduce our staff time needed to write permits for the projects, Region 5 has been working on a general permit to cover these operations. You submit a Notice of Intent and fee to the Board for coverage under the permit. There is no separate writing of WDRs, no separate project review, no separate EIR or negative declaration. You have immediate coverage.

You would have to still submit what we call a pre-application report which goes into site conditions and biosolids loadings for staff approval, but using the General WDRs should take a three to four month process from initial proposal to full approval for application and shorten it to a couple weeks. We feel this is a major step forward in being responsive to the needs of the industry while still fulfilling our obligation to protect water quality.

Staff was also proposing a full waiver of waste discharge requirements for projects using Class A, low metals biosolids. You would not even need coverage under the General Permit. You would deal only the EPA for compliance with the 503s, and with any local regulations.

The General Order follows the pattern of WDRs I discussed earlier. It is a melding of 503 regulations for metals and pathogens, with some extra regulations specific to Region 5. These extra regulations were based on what the Board has adopted in individual WDRs for specific projects, including WDRs which were adopted after the 503s became effective. The general order does not allow all reuse options allowed by the 503s, largely to keep the document relatively simple and readable. We are hoping that the General Order will be used extensively for small, short-term biosolids projects, usually by small cities. Keeping the Order simple is a benefit to the cities in ease of understanding and compliance. The General Order should also work for most large, ongoing sludge application projects. The downside of keeping the General Order simple is that it does not allow all the flexibility possible under federal regulations. Therefore, projects which wish to use options not available under the General Order would have to still get individually adopted Orders, taking substantially longer, possibly requiring a negative declaration or EIR, and opening the project up to public review and comment.

The response to the proposal has been anything but unanimous. Of the 24 comment letters received to date, one has recommended adoption of the proposed orders as written. The other 23 letters have either recommended changes to the orders, or suggested that the orders not be adopted at all.

Comments fall into several categories:

1. Sludge is bad, we can't be sure of what is in it, it is an unnecessary risk to health and the environment. The General WDRs should not be adopted because it would allow continued use of sludge.

2. On the opposite end of the spectrum are the commentors which believe that the 503s fully protect everything and that the State should not be involved in sludge regulation. They feel WDRs are not needed for any sludge reuse projects. Just let EPA handle it.

3. Where the commentors are not opposed to the general order, they are split between two points of view:
   a. We should not require anything beyond the 503s and
   b. Regulation beyond the 503s is needed, but the General Order needs modification.

As an example of the type of controversy, consider setback requirements. EPA has only one setback - a 10 meter (32 foot) setback from surface waters. EPA has no requirement for a buffer zone between Class B sludge and homes. The General Order proposed a 100-foot setback around homes. The commentors wanting only EPA regs, of course, are arguing for no buffer zones around homes. Other commentors have suggested 500 foot or 1000 foot buffer zones around homes. If the Regional Board does adopt the General Order, it will have to decide what, if any, buffer zone will be required between sludge and homes. Whatever decision is made will be unpopular with a large number of people, and that decision is likely to be appealed, further delaying implementation of the General Order.

CONCLUSION

EPA will be directly implementing the new 503 regulations. All the Regional Boards are continuing to write WDRs for Class B sludge projects, adding some restrictions. There is, however, a strong push at many levels to stream line regulations and eliminate duplication of government. Unless regulation of sludge projects by the State provides some necessary level of protection of public health or the environment not provided by the Federal program, the regulation of sludge by the State could be minimized or eliminated. This question will be considered by the Central Valley Regional Board in December. While complete withdrawal of the Regional Board from sludge regulation may simplify permitting for farmers, it also makes them vulnerable to board regulation and citizen opposition.

Quenching Our Thirst

by Rita Schmidt Sudman

"For the first time in recent history, Californians are finding that existing water management systems are no longer able to provide sufficiently reliable water service to users." So states the new California water planning document--a draft report forecasting our water supplies and demands to the year 2020, when the population of California will be 49 million people. It appears that the need to stretch and develop water supplies for agricultural, urban and environmental uses is paramount. And the need to educate the public and decision-makers about water issues remains a vital job.

The Department of Water Resources' draft report, Bulletin 160-93, projects shortfalls in urban and agricultural supplies of between 2.2 million and 4.2 million acre-feet. In most years, according to the report, rising demand will still exceed supply by up to 3.5 million acre-feet - enough water to irrigate about a million acres of crops. Urban needs will increase by 3.8 million acre-feet even with conservation.

For the first time, the state says demand for agricultural water, while still high, will decrease by about 2 million acre feet, primarily because of a projected reduction of 400,000 acres of crops statewide and increased irrigation efficiency. At the Water Education Foundation's recent reporters' briefing, Bureau of Reclamation Regional Director Roger Patterson announced that the federal government next year will begin spending $6.9 million to buy and retire 42,000 to 70,000 acres of San Joaquin Valley land with poor drainage. The funding is authorized under the 1992 Central Valley Project Improvement Act.

All this news comes on the heels of major changes in the operation of the Central Valley Project, increased releases of water to meet requirements of the Endangered Species Act and the end of a six year drought. These changes underscore the need to aggressively manage the state's water resources.

Also the U.S. Environmental Protection Agency is proposing a set of standards to divert more fresh water flows from agricultural and urban users to the San Francisco Bay and Sacramento-San Joaquin Delta Estuary. All contending groups acknowledge that finding solutions to complex Delta problems is key to managing the state' water. In other words, moving the same amount of water or more through the Delta without harming the fish living there is the big challenge to continuation of the state and federal water projects.

So even though the drought was officially declared over, most observers of the California water wars agree that water problems no longer come and go with the weather. No matter how much snow and rain California gets, this new form of drought - sometimes called a "regulatory" drought - continues.

As we enter 1994, it remains clear that the old alliance between the large cities and agriculture to promote water development remains broken. While agriculture supports water project development as the major way to solve the problem of chronic shortages discussed in the state's new report, cities will look more to water conservation, recycling, reuse and water marketing as ways to increase their supply.

Water marketing activity is increasing. At the Foundation's briefing, the first proposed water transfer under the CVP Improvement Act was examined. Assemblymember Rusty Areias discussed his recently negotiated $5.6 million sale of water from his family dairy to the Metropolitan Water District of Southern California.

Despite strong disagreement about how to resolve some of these water issues, it's well to remember that our state has a good water supply. State and federal officials agree that California, unlike its neighbors Nevada and Arizona, has a lot of water and can meet the demands of this fast growing population with rational management. And for agriculture, there are new, innovative projects combining the agricultural benefits and environmental protections. From rice fields in the Sacramento Valley to a tomato cannery in the San Joaquin Valley, partners in these new ventures are working together to combine farming with waterfowl habitat through creation of artificial wetlands.

For as difficult as it sometimes seems for California's diverse water interests to agree on anything, all factions now appear to realize that only through step-by-step compromise and innovative thinking will California resolve its water problems for this generation.

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Opportunities for Biotechnology to Provide a Pro-active Role for Agriculture

Dr. Robert E. Buehler, Monsanto Agricultural Co., St. Louis MO.

Biotechnology provides agriculture with a unique opportunity to pro-actively solve some of the limitations of current production practices. The term 'biotechnology' encompasses a wide array of research areas, each with a unique combination of potential advantages and challenges. One promising area of biotechnology is the genetic engineering of specific agronomic traits in crop plants. This technology provides the ability to manipulate specific desireable traits in crop plants which will benefit consumers and/or producers. The success of genetically engineering agronomic traits in crop plants, as well as other areas of biotechnology, will depend upon technical success, regulatory approval, and public acceptance.

The technical success of genetically engineering of crop plants will depend upon the trait and crop selected. Genetically engineered traits currently being pursued include herbicide tolerance and resistance to various plant pests. Both afford the potential for considerable improvements in the efficiency and environmental acceptance of production agriculture. For example, Monsanto is currently pursuing tolerance to Roundup® in several crops. Roundup® is a broad spectrum herbicide which controls a wide range of annuals and perennials.

Additionally, it possesses an array of environmentallly attractive characteristics such as low toxicity and rapid biodegradability. Thus, by engineering tolerance to Roundup®, producers will have an additional weed control option with excellent environmental characteristics. Several other companies are also pursuing herbicide tolerance in various crops which will provide unique advantages to producers and/or consumers.

In addition to herbicide tolerance, resistance to plant pests such as insects or plant pathogens is often a targeted trait for genetic engineering. For example, insecticidal proteins have been inserted into numerous crop plants. Much of this research has focused on proteins derived from *Bacillus thuringiensis*, commonly referred to as Bt. The Bt proteins are generally quite specific in their activity and will control important agronomic pests while not harming beneficial insects. Also, since the insecticidal component is a protein, it will rapidly degrade upon exposure to the environment. Crop plants, such as corn or cotton, containing Bt genes have the potential to significantly decrease topical applications of insecticides. This decrease in topical applications of insecticides has positive environmental implications. Similar scenarios exist for other genes which impart resistance to other crop pests.

Technical success must be coupled with regulatory approval and public acceptance for production agriculture to realize the benefits of this technology. Regulatory approval requires testing to satisfy both national and international requirements. In the United States, regulatory oversight will be provided by the United States Department of Agriculture (USDA), the Environmental Protection Agency (EPA), and the Food and Drug

Administration (FDA). The role of the USDA is to ensure that the products will not become pests. In the case of genetically engineered plants, the USDA must determine whether an improved plant has the potential to become a weed. The EPA regulates traits which involve pesticidal properties. For example, traits which confer insect tolerance will be treated by EPA as an insecticide. Finally, the FDA's role is to ensure the human food and animal feed safety aspects of the engineered products. In addition to these U.S. organizations, data generated will be used to satisfy anticipated requirements for agencies such as FAO/WHO, Health and Welfare Canada, Novel Foods for European Economic Community, and other agencies.

In addition to the technical and regulatory hurdles, genetically engineered traits must ultimately be accepted by the public. The public, in this case, includes both the producers who would utilize the engineered crops and the consumers who would ultimately purchase the products from these crops. Acceptance by both groups will require coordinated efforts by industry, universities, commodity groups, and consumer groups.

Genetic engineering of crop plants provides some unique opportunities to address some of the challenges currently facing production agriculture. The ultimate impact of this technology will be determined by the technical feasibility of altering specific traits, the ability to gain regulatory approval, and the public's acceptance of the products of this technology.

"Working Together" To Improve Water Quality

Phil Osterli, County Director, UC Cooperative Extension, Stanislaus County

Mike McElhiney, District Conservationist, USDA Soil Conservation Service, Patterson

Paul Hansen, Post Graduate Researcher, UC Cooperative Extension, Stanislaus County

It has become a tradition in Stanislaus County, California for Agricultural and Conservation Leaders to "work together" to accomplish soil and water conservation goals. That tradition has been validated and strengthened by U.S.D.A.'s Water Quality Initiative and specifically by the on-going West Stanislaus Hydrologic Unit Area Project (HUA). The type of success this paper will focus on will be the type of progress that is hard to measure and quantify, yet imperative and invaluable in order to accomplish the objectives of the project.

Traditional parternerships and coalitions between the local Resource Conservation District (RCD), Soil Conservation Service (SCS), University of California Cooperative Extension (UCCE) and the Agricultural Stabilization and Conservation Service (ASCS) have never been stronger. We recognize that none of our agencies can be all things to all people and that we all have specific roles to play to deliver this project in a coordinated and integrated way. We are very fortunate to have a history of "good people" working together towards a common goal. We have seen changes coming, and are becoming comfortable with those changes. We are much too busy with our individual charges to worry about turf, and the type of people involved would probably not tolerate such behavior if it surfaced.

The foundation of today's success began over 15 years ago with a concern by local, state, and federal agencies that a sediment problem existed. Today, the agricultural community recognizes that there is a problem, that the problem needs to be fixed, and that perfectly acceptable practices of yesterday are no longer acceptable today. These changes in perception did not just happen out of thin air. It has taken years of people working with people, communicating, and participating in countless meetings, workshops, tours, news articles, newsletters, video productions, brochures, and personal contacts. Sediment reduction is now a topic that can be heard in coffee shops throughout the area.

The intangible "people working together" process serves as a cornerstone of the HUA. The foundation has grown to support a variety of measurable and tangible outcomes, that have been included in various reports. The combination of tangibles and intangibles have led to a perception locally, as well as with the regulatory agencies, that the participants in the HUA are doing a good job improving the quality of the San Joaquin River.

The HUA has developed considerable momentum in the three years since its beginning. It has become a catalyst for action, where the combined efforts have added up to more progress than thought possible. Individual agencies have participated in the project according to their specific roles. UCCE has functioned in its role of providing education and conducting applied research, SCS has provided technical assistance, ASCS has been responsible for administering the Water Quality Incentives Program (WQIP) cost-share program, and the RCD assists the SCS and CES with their educational efforts. Before describing specific accomplishments of the HUA, some information should be provided on recent environmental legislation that has added impetus to our efforts.

The Inland Surface Waters Plan (ISWP), required by the Clean Water Act, was adopted by the State Water Resources Control Board to set regulatory controls on the discharge of waste to surface waters. Three approaches for implementation of needed conservation practices will be followed: (1) voluntary implementation of conservation practices; (2) regulatory based or institutional based encouragement of practice implementation; and (3) regulation such as issuance of Waste Discharge Requirements which establish effluent limitations and/or discharge prohibitions. Local drainage entities have been established and are responsible for prioritizing, implementing plans and monitoring local discharges. Within the framework of the ISWP, a "West Stanislaus Sediment Reduction Plan" was produced by SCS Water

Resources Planning Staff in cooperation with the State Water Resources Control Board and the Regional Water Quality Control Board.

The "West Stanislaus Sediment Reduction Plan" represents an important document that has been produced to assist the HUA. The study highlights the extent of the problem: it estimates that potentially over 1 million tons (more than 400 acre feet) of sediment that is contaminated with organochlorine residues reaches the San Joaquin River annually as a result of irrigation induced erosion. In addition, the study evaluates best management practices (BMP's) in terms of effectiveness and cost, and provides an implementation plan that is consistent with the ISWP. The plan "emphasizes that the best solution is a local solution. Local growers should try and solve the problem with methods that are easy for them to integrate into their existing 'operations' and not wait until solutions are dictated by a regulatory agency."

To determine the extent of voluntary participation and to assist in developing a plan to encourage voluntary implementation of BMP's, an SCS sociologist was utilized. He concluded "...Participation in the project is estimated to be high: 71 % of the population, affecting 81,181 acres. The primary reason for the encouraging participation estimate is that a significant number of growers are aware of the water quality problem and its possible solutions. Remarkably, most area growers have at one time used, or personally witnessed, one or more of the recommended BMP's... The project has the potential to make a substantial contribution to reducing contamination of the San Joaquin River. Grower participation can be expected to be high with only minimal resistance..." This account of early efforts shows that the foundation for change was well-established.

Utilizing this base of knowledge, in the past year, all cooperating agencies cooperated closely with one another on an Information and Education Program, designed to continue to promote an understanding and participation in the project. Advanced irrigation management techniques, including the use of emerging irrigation technology, were promoted through media contact, educational material, and a scheduled workshop on Water Quality, IWM and BMP's. The local media and correspondence were used to inform farmers about the need for cost-sharing and available technical assistance.

UCCE, cooperating with other agencies in its educational efforts, provided educational assistance through workshops held in cooperation with respective irrigation districts and growers, one-on-one field consultations, field days, grower information publications, video distribution, and demonstration sites. Educational materials were developed and distributed that focused on non-point source pollution (NPSP) and BMP's. A poster presentation was jointly prepared and used to demonstrate the objectives, problems, and solutions of the HUA at various meetings. A video on Best Management Practices and a video in Spanish on "What The Irrigator Can Do To Control Erosion and Minimize Sediment Movement From The Field" were distributed through irrigation district boards and participating agencies. The monthly newsletter "Westside Water" currently has a mailing list of more than 650, and has covered such topics recently as BMP's for sediment reduction (7/93), recognizing irrigation erosion (8/93), and irrigation efficiency (9/93).

A small scale 319 Demonstration Project, which was proposed in 1990 in the HUA, has been headed by the RCD and has provided an opportunity to evaluate BMP's in the field. An RCD employee has been monitoring on a daily basis irrigation induced erosion, collecting tail water samples for Total Suspended Solids analysis in the RCD Field Laboratory.

In an effort to increase one-on-one contact with and provide technical assistance to growers, the RCD has recently entered into a contract with Power Hydrodynamics to provide a Mobile Irrigation Laboratory for irrigation and drainage evaluations. The California Department of Water Resources is providing funding for this service.

A promising new technology has been the focus of much recent research by the UCCE and SCS.

Field demonstration sites were developed by CE to quantify the effects of polymers (polyacrylamides) on water infiltration rates and irrigation induced erosion. With funding augmentation from the polymer manufacturer, two detailed field trials were conducted using low rates (2.5 to 10 ppm) of polymer metered into the irrigation water. The treated water resulted in measured 10 to 45 percent increases in water infiltration, and reductions in suspended solids and associated irrigation induced erosion by over 85 percent. Follow-up commercial scale field demonstrations showed effective results with rates as low as 1 ppm. It does not appear that any adverse ecological impact would result from these anionic polymers, but further review may be required by regulatory agencies to insure safety to wildlife and the environment. Use of polymers was proposed to be added to WQIP cost-share management practices, and several papers have been prepared describing this application of polyacrylamides. Details of the initial polymer research were recently published in the September-October 1993 issue of *California Agriculture*.

In conclusion, much has been accomplished in the HUA project to date, even though there has been a substantial adverse economic impact of the recent drought. Growers lack capitol to spend on conservation practices that do not directly benefit their income. It is expected that the WQIP will enable farmers to invest in BMP's and therefore reduce the sediment leaving their fields. The ASCS has increased the cost-share percentage from 50 to 75 percent, which should make changes more economically feasible. Research will continue on polymers and their possible uses in sediment reduction. With current technology and possibly new technology water-quality objectives can be met. Further progress is envisioned as agencies continue to cooperate and make further plans to facilitate implementation of conservation practices.

THE ROLE OF AGRICULTURE IN PM_{10} ATTAINMENT IN CALIFORNIA

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ABSTRACT

An Agricultural PM_{10} Advisory Committee was formed in March of 1989, which represented a wide range of agricultural interests in eight counties of the San Joaquin Valley. The initial group consisted of the U.S.D.A., Soil Conservation Service, the University of California Agricultural Extension, and the Fresno County Department of Agriculture. This group was later expanded to include Fresno County Health Department, Oil Producers, the Building Industry Association, Cal Trans, the Bureau of Land Management, the Construction Industry, the California Air Resources Board, and the Environmental Protection Agency (EPA). In May 1991 the advisory group led to the formation of the San Joaquin Valley Citizens Advisory Group of Industries for "Air Quality", to allow effected groups to work together on the air quality issues in the San Joaquin Valley and the State.

INTRODUCTION

The major issues are:

1. Determination of effects of Federal Clean Act of 1990, California Clean Air Act and other statutes effecting the agriculture industry:

   The advent of Amendments to the Federal Clean Air Act and the requirements of California Clean Air Act have created additional mandates upon the agriculture industries. One of the heaviest impacts of these statutes is in the area of PM_{10}. The Advisory Group has been instrumental in communicating the mandates and the farmers concerns between the regulatory agencies and the agriculture industries.

2. Determination of accuracy and appropriateness of the published emissions inventories, emission factors, control practices, best management techniques, seasons, and air quality regulation. The agricultural Advisory Committee believes that sound factual data, and information should be the basis for regulation. The Advisory Committee also believes that good science must be employed prior to assessing additional environmental mandates. In the area of PM_{10}, many emissions factors employed to arrive at the emissions inventory are either outdated to do not apply to the specific conditions of the San Joaquin Valley. the inappropriate values are later used as a regulatory tool to promulgate rules on the industry.

The new rules developed without adequate scientific facts yield to incorrect control measures that create unneeded burden upon industries. The Advisory Group has been instrumental in obtaining EPA funds to study the emissions factors selected agricultural practices. This study along with the future studies will aid Air Pollution Officials as well as the agriculture community to gain a better understanding of the causes and nature of PM_{10}. The Advisory Group believes that by increasing the regulated communities' understanding of the PM_{10}, the control measures would be most effective since compliance will embraced voluntarily with education.

3. Development of an adoption and implementation schedule for specific control measures considering technological feasibility, total emission acceptability, and enforceability. This goal will be achieved through the PM_{10} study efforts. The first phase of the PM_{10} will be completed in the next few months. The remaining four phases of the PM_{10} studies in Agriculture and other industries will be completed in the upcoming five years.

4. The second phase on the study focuses on the formation of secondary particulate under the Valley winter conditions. This state of art study will provide valuable information for future coordination of PM_{10} plan with the expected reduction from secondary precursors of PM_{10}. The federal government has already allocated funds to initiate the study. The study will be performed under the direction of the existing San Joaquin Valley Study Agency (Formerly SARMAP) with assistance from CARB, EPA and the industries.

5. The San Joaquin Valley Unified APCD, drafted the "New Fugitive Dust" regulation VIII. The project was supported by EPA and private industries from the SJV. This regulation is a part of the San Joaquin Valley Unified APCD PM_{10} Attainment Plan. The first phase of this regulation is scheduled for adoption in October 1993 and implemented in January 1994. The District is developing a scoping document for the serious area PM_{10} plan and will be submitted to EPA by August of 1994.

6. The State of California and air districts must seriously and vigorously attempt to address the PM_{10} issue. PM_{10} has always taken a second seat to ozone, despite the State Air Resources Report to the Legislators which states more people are exposed to harmful levels of PM_{10} than any other pollutant including ozone, the State still does not have a clear agenda for PM_{10}.

7. The local air districts have taken the leading role in extensive PM_{10} planning with the help of the industries of the Valley. The cooperation between the district and the industry will cause the implementation of federal mandates to be harmonious and effective.

BODY

The study of the emission of Fugitive PM_{10} Emissions from Selected Agricultural Practices on Selected Agricultural Soils 1991 Phase 1: Federal and State government have established standards for fine particulate matter in air. Air quality standards for particulate matter with aerodynamic diameters of less than 10 microns (PM_{10}) are not being met in the eight county San

Joaquin Valley Air Basin. The San Joaquin Valley Unified Air Pollution Control District, pursuant to the requirements of the Federal Clean Air Act has developed a plan that requires control strategies to reduce concentration of particles in the air.

These control measures are targeting sources that according to the District emissions inventory contribute the most to the Valley's PM_{10} problem. Existing inventories of PM_{10} emissions from agricultural operations and from exposed soil do not accurately identify or quantify individual sources. therefore, an inaccurate inventory is used to develop control measures.

Specific types of information, tools and techniques are needed to develop an inventory and the management practices that will most likely be part of the control strategies.

They are:

* What constituents of PM_{10} are the most harmful, and therefore the most critical to control first:
* What are the relative contributions of local versus transported pollutants contributing to PM_{10} problems at receptor sites?
* Would it be possible to assemble an inventory of emissions of PM_{10}, who are the "actors", and which season is the most prevalent to the activity?
* Is it possible to determine the chemical and physical features of PM_{10} that could discriminate sources?
* Which agricultural activities contribute the most to PM_{10} generation?
* Is it possible to conduct a serious cost-benefit analysis of PM_{10}?
* What kind of tools are needed to accurately measure PM_{10} emissions from a field?

* A workable, validated model or models for predicting PM_{10} emissions.

Unfortunately, regulatory deadlines for attainment do not allow time for the needed research prior to implementation of productive (versus assumes) strategies. Thus, in the absence of good science, "Common sense" suggestions for PM_{10} abatement need to be identified for practices that will result in the greatest reduction of PM_{10} emissions. Information collected should be applicable to long range and short range research.

SHORT TERM OBJECTIVES

The current study is limited to the short term objectives of identifying practices and conditions which contribute significant amounts of PM_{10} emissions and easily identifiable practices for PM_{10} reduction.

The tasks undertaken are:

1. Develop and test an instrument and methodology for easy on-site determination of PM_{10}.
2. Correlate PM_{10} measurements needed with the methodology developed in task one with more sophisticated methods.
3. Conduct an on-site assessment of farming practices under actual conditions which exist within the San Joaquin Valley Air Basin using the methodology developed in task one. Record weather conditions, wind speed and direction, farming practice, soil type, surface soil moisture content and visual observation of dust.

Make

measurements at appropriate distances upwind and down wind of each site.

4. Identify which practices, conditions and soil have the highest propensity for PM_{10} emissions.
5. Develop and validate a system for estimating PM_{10} emissions from agricultural operations which accounts for all significant variables.
6. Identify best management farming practices for PM_{10} reduction that can be readily, qickly, efficiently and economically implemented.

The primary focus is on those soils, practices and condition presumed to have highest PM_{10} emissions and, therefore, provide the greatest potential for PM_{10} emissions reduction. This strategy assumes that PM_{10} emissions occur with visible dust emissions as determined by opacity readings, and that workable solutions can be determined and implemented for reducing dust emissions from given farming or soil movement practices. The study limits the assessment to soils to those identified by the USDA-SCS as having a high wind erodibility index (greater than 86) a few soils with lower indices for comparison and to the practices and crops are listed below.

Situation/Practice	**Crops**
Spring land preparation	Cotton, dry beans
Fall land preparation	Cotton, dry beans, small grains, alfalfa
Disking	Cotton
Stalk shredding	
Land leveling	
Land planning	

Equipment traffic on dirt roads	
Sulfuring	Grapes
Cattle feed lots	
Dairy feed lots	
Preparation for harvest	Raisin grapes, almonds, figs, walnuts
Harvest	Almonds, figs, walnuts, cotton, small grains, dry beans
Open land with various surface conditions	

CONCLUSION

For these reasons, we are in strong support of a multi-year program of field monitoring, emissions modeling, data analysis, and understanding of emissions sources, the composition and dynamics of PM_{10}, and identify those control strategies and technologies that are feasible, cost-effective and achieve the most reductions in PM_{10}. This new understanding will help ensure that future emissions controls will be effective in achieving improved air quality.

It is important to note that the study is intended to provide information not only specific to the development of an effective attainment plan within the San Joaquin Valley region, but also improved methods and tools for monitoring, emission estimation, control strategy development and modeling that can be used to develop effective PM_{10} emission reduction programs throughout the nation.

To bring this very important study to fruition, it will take a shared effort by all participants. Preliminary scoping cost estimated for the study are approximately $23.5 million over the next five years, to be provided by a consortium of sponsors in both the private and public sector. Of this, one half or $11.5 million would be borne by the Federal government and one half through a combination of private industry or other State and local sources.

As you may be aware, in 1991 a $320,000 grant from the Federal Environmental Protection Agency (EPA) was secured to kick off the study effort o evaluate emissions from various sources of PM_{10} such as paved and unpaved roads and agricultural practices associated with harvesting of various crops in addition to looking at various control measures. In addition, $1.4 million contributed by EPA in fiscal year 1993 from the VA-HUD-Independent Agencies bill augment the program and is again being requested from the appropriations allocated for the EPA in fiscal year 1994. The California Air Resources Board (CARB) has earmarked $1 million each for the next three years towards this effort along with other local government, business and industry funds. Currently efforts are also underway to secure $1 million each for the next five years in U.S. Department of Agriculture and agencies in fiscal year 1994 as PM_{10} is a critical issue to the entire agricultural community and the nation.

The Importance of Being Proactive in Developing Community Based Support: The Case of Silverleaf Whitefly - An Emerging Pest Management Crisis:

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The problem

Cotton production in the San Joaquin Valley (SJV) is the envy of the world. It is easy to see why with yields averaging 2.8 bales/acre, its high quality lint bringing premium prices, and insect pressure requiring less than 3 insecticide applications per year. The key insect pests of cotton are lygus bugs which directly on the developing floral bud and spider mites which feed directly on the foliage. During the 1980's, cotton aphid infestations have caused concerns about lint quality and the threat of sticky cotton. Aphids secrete honeydew, a sugary by-product of their feeding process, which sticks to the cotton lint. This sticky, sugary deposit can cause major problems in cotton gins and textile mills, can result in a reduction of quality premiums, and, at worst, loss of markets.

The introduction of Bemisia tabaci, Silverleaf or Sweetpotato whitefly Strain B (5,7), into the SJV in 1992 has caused much concern. This pest has caused extensive damage in the Southern desert valleys and Arizona to cotton, melons, alfalfa, tomatoes, and cole crops. In addition, it has a become major nuisance in the urban setting in these areas. Loss estimates in Imperial County alone exceed 111 million dollars for fall and winter 1991-92 and secondary effects on employment add to the regional loss (4). Nationally, conservative loss estimates exceed 200 million dollar in 1991 (6).

To cotton growers, the production of honeydew by the whitefly is a serious problem. The cotton industry in Arizona suffered not only major losses due to the direct feeding of this pest but suffered long term damage in the loss of their reputation because of sticky cotton. Silverleaf whitefly can vector destructive geminiviruses as well as cause direct physiotoxic symptoms (3).

In the SJV as in other regions, this pest has a wide host range and can build up to high numbers. Swarms of whiteflies are present in urban and rural areas by the end of summer and Silverleaf whitefly will use a number of crops in sequence to develop to high populations. Populations are at their lowest numbers in winter when they are forced into sheltered locations such as protected ornamental plants near homes. During spring, melons and tomatoes can act as initial foci for field invasion. Cotton is the primary host from May until August and is the host on which whitefly populations build to high numbers during August and September. After cotton is defoliated, whiteflies migrate to alternate hosts such as fall and winter vegetables (especially melons, egg plant, and cole crops) which can be severely affected.

In 1992 this pest was recognized as a potential problem in SJV after the discovery of field populations around Bakersfield in Kern County. In that year, California Department of Food and Agriculture personnel conducted a random survey of cotton adjacent to pink bollworm traps and found 38.8% of the locations were infested (5). A similar survey in 1993 found that 75.3% of the sample locations were infested (Keaveny pers. comm.). Random surveys in Tulare and Kings Counties has found this pest to be widespread but generally at lower densities.

It is apparent that Silverleaf whitefly is established and expanding its range in the SJV. This pest with its wide host range, its capacity for exponential population increases, and its potential for triggering widespread insecticide applications is a major threat to the cotton IPM program developed over the past 25 years. Based on experiences in Arizona and southern deserts, it is also apparent that regional management approaches are required in order to manage such a versatile pest. Such approaches will include regional chemical resistance management, cooperative crop planting sequences, host free periods, area wide agreements on planting and crop destruction dates, and area wide sanitation (2). Fundamental to such regional, cross-commodity programs is the recognition of the importance and the need to organize the community to meet this threat.

Organizing industry's response to the threat

In October 1992, Cooperative Extension organized a meeting to bring together the various agencies who are involved with this pest. These included CDFA, UC Experiment Station, UC Cooperative Extension, USDA ARS, and County Agricultural Commissioners. The purpose of this meeting was to review the current situation and discuss plans for 1993. This meeting successfully brought together the primary governmental agencies and developed the ground work for cooperative and productive interactions. However, the experience provided from the southern deserts drove home the message that only community involvement and commitment would provide the long term solution to this problem.

A model of such community organization is in place in Imperial County in the form of Imperial County Whitefly Management Committee. The stated purpose of the Committee is to coordinate and prioritize research, coordinate information dissemination and situation reports, and cooperate with those outside the area in seeking solutions (1). The Committee has the power to assess its members to accomplish these tasks.

In March of 1993, invitations were sent to representatives of key commodities including cotton, melon, carrots, beans, alfalfa, fresh fruit, fresh and processing tomatoes as well as individual producers and PCAs. The purpose of the meeting was to provide the industry an opportunity to discuss the value of establishing a management committee similar to Imperial

County's. Representatives from Imperial County were present and made a passionate plea to take this pest seriously. It was pointed out that this committee was formed as a *reaction* to the crisis while the SJV has the opportunity to be *proactive* in its approach. The SJV has the opportunity to organize a community effort to manage this pest while it is still in its invasive stage before it becomes a severe problem.

While interested and concerned about the potential threat, SJV growers and allied industries were reluctant to form a committee similar in structure to the Imperial Valley. First, the SJV is different from the Imperial Valley in its size, its temperature regime, its surrounding ecological communities, and its crop mosaics. The full impact of the pest has not been determined, either in its geographical distribution or its potential for developing extremely high population densities. Second, because no major economic threat had yet occurred in the SJV, there was little interest in creating additional committees. SJV producers already have a number of boards and committees established, and it was felt these could be used to handle the problem.

However, the unanimous opinion of the participants was for the various research, extension, and regulatory agencies to continue to meet monthly. The charge from them was to follow the developing whitefly situation closely and keep the industry informed. This group called the Silverleaf Whitefly Management Group, met monthly from March until November, 1993.

The San Joaquin Valley Silverleaf Whitefly Management Group

The purpose of the monthly meetings was to review the status of the whitefly's distribution, update all members on research and extension progress, provide a forum for general discussion, and have a keynote speaker present a topic of interest. The Group was informal and anyone interested was invited to attend. The key participants include UC Experiment Station, UC Extension, County Agricultural Commissioners, CDFA, and commodity and PCA representatives. The meetings were supported by grant from the California Cotton Pest Control Board as was the dissemination of the meeting's summary. Through this coordinated effort, resources were applied to projects in a non-duplicative manner. For example, regional surveys to quantify the contribution of various plant species to the population increase of whitefly was handled by UC, widespread survey work to monitor general distribution was handled by CDFA, and coordination of information was handled by Extension.

The dissemination of information took place in several ways. Information was provided in a traditional fashion through monthly cotton production meetings, newsletters, and Farm Advisor contacts. The Pink Bollworm Control and Eradication Unit (CDFA) disseminated information through their weekly newsletter. In addition, several novel approaches were tried. First, a telephone hotline was established which used a toll free number (800 880-0981) and provided updates about the whitefly. This was supported by the Cotton Foundation and Valent Chemical.

The hotline received 250 calls between July and September, including 75 from outside the SJV area. Second, a computer bulletin board system (BBS) was established (209 646-3958). The BBS provides similar information in regards to whitefly situation reports but had the advantage of allowing for the complete review of the reports. In addition, text information, such as lengthy reports or reference material, could be stored for retrieval by the user. There are currently 18 users registered on the BBS, the majority being public agency personnel and the remainder split between industry and PCAs. The BBS was supported by the California Cotton Pest Control Board.

The BBS and telephone hotline provided the opportunity for interactive communication. In both cases, users were encouraged to leave any information they might have about the whitefly or express specific concerns about the problem. On the BBS, a continual dialog can be established in which any user can participate. Such discussions are called "forums" but we referred to them as "electronic coffee shops". They provide the opportunity for far flung individuals to communicate expertise, concerns, and solutions as if they were in the same room. Unfortunately, very few users took advantage of its interactive approach and primary use was passive reception of information. We received very little feedback from hotline users and none from BBS users. It is hoped that the value of such interactive opportunities will be exploited as their value becomes more widely known.

Summary

One of the world's most destructive pests has established in the SJV. While the distribution of this pest expanded during 1993, it had little widespread economic impact on agriculture. Predictions for continued problems of greater magnitude make it imperative that community based proactive management programs get underway. The San Joaquin Valley Silverleaf Whitefly Management Group has provided the framework for such programs by coordinating research, survey, and extension between various public and private agencies. The lack of commitment in forming a more active management committee similar to Imperial County stems not from a lack of concern, but I believe from a lack of need, at least in the immediate future. Evidence of this concern can be found in the support provided by industry not only in their dollars but also in their involvement in monthly meetings.

It will be the responsibility of the SJV Whitefly Management Group to ensure that the industry is well prepared for the potential problems in 1994. These responsibilities will include the preparation of best management practices well before the need exists, continued monitoring of whitefly population development, and rapid information dissemination for maximum management lead time. In addition, this committee provides essential framework for connecting to the agricultural community leaders in the event a more rigorous structure is required to deal with a larger crisis.

Useful References

1. Birdsall, S.L. 1993. Mission Statement: Whitefly Management Committee. 1 page leaflet.

2. Ellsworth, P.C. (editor). 1993. Sweetpotato Whitefly in Arizona. 4 pp.

3. Gilbertson, R.L. 1993. Whitefly-transmitted geminiviruses: A potential threat to California Agriculture? 4 page leaflet.

4. Gonzalez, R.A., G.E. Goldman, E.T. Natwick, H.R. Rosenburg, J.I. Grieshop, S.R. Sutter, T. Funakoshi, S. Davila-Garcia. 1992. Whitefly invasion in Imperial Valley costs growers, workers millions in losses. California Agriculture, 46(5): 7-8.

5. Gruenhagen, N.M., T.M. Perring, L.G. Bezark, D.M. Daoud, and T.F. Leigh. Silverleaf whitefly present in the San Joaquin Valley. California Agriculture, 47(1): 4-6.

6. Henneberry, T.J. 1993. Sweetpotato whitefly - Current status and national research and action plant. Proceedings of the Beltwide Cotton Production Confeences. Vol. 2 663-665.

7. Perring, T.M., C.A. Farrar, T.S. Bellows, A.D. Cooper, R.J. Rodriquez. 1993. Evidence for a new species of whitefly: UCR findings and implications. California Agriculture, 47(1): 7-8.

AGRICULTURE AND THE ENVIRONMENT: CASE STUDIES IN CALIFORNIA RICE

James E. Hill and John F. Williams[1]

Internationally, research and education in agriculture focused on production for most of the twentieth century. In rice, the need to increase food supplies for a rapidly expanding world population was paramount, and the influence of agricultural practices on the environment was secondary. The green revolution in rice more than doubled world production in the last 30 yr. However, the demand for food continues to increase even with lower birth rates in many asian countries. Nearly half the world's population remains dependent on rice for its primary food. The International Rice Research Institute (IRRI) in the Philippines estimates that rice production must increase more than 60% to meet food needs by the year 2030 (IRRI 1989, IRRI 1993). In land-poor asia, these needs can only be met by more intensive, but environmentally compatible farming practices.

California rice production has undergone substantial changes since its introduction to this state after the turn of the century (Willson, 1979; Hill et al., 1992). The adoption of semi-dwarf varieties, intensive fertilization and plant protection chemicals paralleled the changes which occurred in the green revolution in asian rice production. Coupled with other technologies, such as laser leveling and highly developed irrigation systems, California yields are the highest worldwide exceeding 8000 lb a^{-1} (9 t ha^{-1}) over the period 1991-93. For the first 50 yrs of the industry research emphasis was on production.

However, Rachael Carson's controversial book, Silent Spring (Carson, 1962), not widely embraced by the agricultural community, marked the beginning of an era of public scrutiny of agricultural practices by an increasingly urban U.S. population. In California, few commodities have been more in the pubic eye than rice. For more than two decades water quality, air quality, and in drought years, water quantity, have been at the forefront of environmental concerns in rice. For example, fish kills and off-tastes in potable water from the off-site movement of herbicides brought public criticism to the California rice industry in the late 1970s. Since 1970 air pollution from rice straw burning has been a major issue. And questions of water

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consumption are driving an industry-wide conservation effort. Rice growers have and are continuing to make remarkable achievements through a proactive stance in mitigating these environmental concerns. Their work in addressing air quality, water quality and water allocation issues should serve as example for other commodities and for rice-based cropping systems worldwide.

Water Quality

In the late 1970s fish kills in the agricultural drains of the rice growing areas of the Sacramento Valley were attributed to the herbicide molinate. Early in the next decade a sulfoxide metabolite of the herbicide thiobencarb was implicated as the cause of an off-taste in the municipal drinking water of the City of Sacramento. The metabolite was never detected in potable water, but the herbicide itself was found in the Sacramento River at the intake of the drinking water treatment facility. The appearance of the herbicide coincident with the off-taste in potable water, and taste panel evaluation of metabolite spiked water samples provided sufficient circumstantial evidence that off-site movement of the herbicide was responsible. Public outcry was immediate, with both the City of Sacramento and the press calling for a ban on the use of these herbicides in rice. The intensity of watergrass competition in rice (Hill et al. 1989), however, would have made such a ban disastrous for rice production. A Rice Pesticide Working Group was formed by the California Department of Food and Agriculture (CDFA, now Cal EPA) including the Sacramento Valley Regional Water Control Board, the Department of Fish and Game, the Department of Health Services as well as CDFA. The University of California, and most importantly, rice growers, were represented in this group.

Conventional rice irrigation systems were designed to facilitate water depth management by allowing a continuous flow of water through a series of basins in the field. In-levee weirs (rice boxes) maintained water depth control by allowing excess water to flow out of the field. Herbicide registration labels were thus developed as a compromise between holding water static for good weed control and allowing water flow as soon as possible for convenience in managing irrigation.

The Working Group's principal strategy to mitigate against herbicides moving off-site was to increase in-field water holding beyond label requirements. The half lives of molinate and thiobencarb are short lived, 4 d and 8 d respectively, thus longer holding periods allowed greater degradation. But Longer holding periods were difficult to manage and potentially damaging to the crop. The initial reaction by some growers was negative, arguing that conventional systems were not designed to hold water for long periods and that alternative irrigation strategies were too costly. As an incentive to develop permanent solutions for water containment, earlier draining was allowed in fields, or groups of fields, where tailwater recovery systems were installed. Progressive growers installed recirculating systems and developed novel static or tailwater recapture systems (Hill et al., 1991). Even fields with conventional irrigation, despite inherent problems with excess buildup of water in the lower basins, were better managed as growers increased their efforts to keep herbicide-treated floodwaters from escaping.

Over the past decade, water holding periods following molinate application were increased from the label requirement of 4 d to 19 d, and thiobencarb to 30 d (Table 1). Herbicide levels in the Sacramento river and its tributaries were monitored to track the success of increased in-field water holding on rice herbicide discharges. From 1982 to 1992, rice herbicide mass discharge into public waters had been reduced by over 98% (Figure 1, 2). Challenges remain, including 1) regulatory mandates to meet even more stringent residue performance goals, 2) the need to accelerate conversion of the remaining rice acreage under conventional irrigation to more controlled irrigation systems, and 3) the development of agronomic practices to enhance stand establishment and reduce herbicide use. Through innovative irrigation management, most rice growers have accepted and adopted, what few thought possible only a decade ago.

Rice Straw Management and Air Quality

Straw yields are approximately equal to grain yields in California rice production (Roberts et al., 1993). Thus 3 to 4 t a^{-1} of straw remain in the field after harvest (Hill and Peter son, 1981). Historically, rice straw has been burned for several reasons: 1) the sheer magnitude of incorporating 4 t of straw in often wet soils is formidable, 2) burning controls rice stem diseases, and 3) burning is relatively inexpensive (Blank et al. 1993). Burning, however, is no longer acceptable to a majority of the public. In 1991 growers participated in developing legislation for a phase-down of burning. The Rice Straw Burning Reduction Act (Table 2) phases down burning over several years to give growers time to learn and adjust to alternative methods of handling straw. By the year 2000 burning will be allowed only under special circumstances, and on no more than 25% of the acreage under a safe harbor clause. Straw can be handled in three ways--burning, returning it to the soil or removing it from the field.

Considerable research has demonstrated many potential uses for straw but none are economically viable. Possible uses for rice straw include energy production, building materials, paper and the production of intermediate chemical products (UC, 1981). Technical feasibility, quality of the finished product and continuity of supply are also issues. Thus, the phase down of burning means straw incorporation is the most practical near-term alternative. Many growers are relying on conventional equipment such as discs, plows and chisels to incorporate rice straw. Combine-mounted, towed and self-propelled choppers are often used before incorporation to improve the handling characteristics of straw and soil contact for more rapid decomposition. Some nontraditional equipment is also being used as growers experiment to find a least cost method. One innovative technique involves flooding the field after harvest and mashing the straw into the soil with a light weight cage roller. The floodwater remains in the field to improve waterfowl habitat. This method has received the accolades of environmental groups, and even funding, to promote the practice. Straw decomposition under winter flooding is the least studied method of disposal, but it appears to work satisfactorily. And the proactive alliance with environmental groups based on this method, has greatly enhanced the image of the rice industry.

Early experimentation on straw incorporation by rice growers has been mostly positive. Varieties with 30 d earlier maturity developed in the last 15 yrs and well-drained laser leveled fields have been important to these successes. Favorable fall weather in the two years following the implementation of AB 1378 has also been very helpful. Early rainfall could defer straw incorporation to the spring, making crop problems, such as rice diseases, N deficiency and gas toxicity more likely. It is too soon to judge the long term effects of incorporation, but public and private research will undoubtedly improve the technology for straw disposal.

Water Conservation

Increased water demand in combination with drought in California has cast much attention on agriculture, the heaviest user. The rice industry, with its highly visible flooded fields and relatively large acreage, has received the most pressure from non-farm interests to re-allocate water for other uses. Even before the drought of 1987-92, some rice growers in high water cost areas had installed tailwater return systems to improve efficiency and to enable acreage expansion. In many areas, however, water remained cheap and plentiful and growers had little incentive to save water. As California and Federal Water policies shift water to environmental uses to improve wetlands in wildlife refuges and increase stream flows for endangered migratory fish, the rice industry has begun to adjust its practices.

Diversion of water for use in rice, nearly 8 a-ft a^{-1} two decades ago, is now below 6 a-ft a^{-1}. Contributions to the average estimated water use in rice are 3.0, 1.5 and 1.5 a-ft a^{-1} for evapotranspiration, outflow and percolation respectively (Table 3). Most of the improvement has come from reduced out flows. Land leveling with laser-guided equipment began approximately in 1970, leading to precision leveling a high percentage of California rice fields. Level fields permit better water management, including minimal spill.

The practices to improve water quality described above have also been instrumental in reducing water use. Water is now held early in the season, a period when large amounts of water were previously spilled as growers struggled to establish desired water depths. Having learned that water could be held during this critical period, many growers now practice minimum or no spill throughout the season. Some water districts have encouraged this process by adopting minimal spill policies. Return and containment systems are increasingly used to conserve and to protect water quality.

Higher water cost is also stimulating conservation, brought about by increased reliance on more expensive groundwater to replace the loss of some surface sources. Federal water is also more expensive because of fees collected for environmental purposes. Seasonal average water cost is estimated at \$50-60 ac^{-1} for rice, up sharply from only a few years ago.

The adoption of early maturing rice cultivars has, to a lesser extent, contributed to improved water use. Varieties with 30 d earlier maturity reduce water use by about 0.3 a-ft a^{-1}, compared to long season varieties.

Rice growers are adopting many cultural practices to save water, but they are also moving to secure their water future by affecting policy at local, state and federal levels. Through organizations such as the California Rice Industry Association (CRIA), and coalitions with other organizations such as the Northern California Water Association, the rice industry is providing water use awareness programs which influence public perception and policy on rice water use.

Summary

The California rice industry has taken a proactive stance on issues of water and air quality and water use. In less than a decade, through the innovation and adoption of new and improved irrigation management strategies, downstream pollution of herbicides in the Sacramento River and its tributaries have been reduced by 98%. More recently, the rice industry actively participated in the development of legislation to phase down rice straw burning. Rice farmers are now experimenting with various methods of straw disposal, including innovative practices to enhance waterfowl habitat, all more expensive than burning. Much less rice straw will be burned so the program will be successful in improving air quality. Aside from higher costs, the early experience with rice straw incorporation has been generally positive, but more information is needed on straw decomposition and alternative uses. Similar programs on water conservation are making progress in reducing water use. The industry's proactive approach to environmental concerns related to rice farming has been highly successful in forging coalitions with environmental and other public groups.

Literature Cited

Blank, S. C., K. Jetter, C. M. Wick, and J. F. Williams. 1993. Incorporating rice straw into soil may become disposal option for growers. California Agric. 47(4): 8-12.

Carson, R. 1962. Silent Spring. The Riverside Press, Cambridge, Haughton Mifflin Company, Boston. 368 p.

Hill, J. E., S. K. DeDatta, and J. G. Real. 1989. Echinochloa competition in rice: Comparison of studies from direct-seeded and transplanted flooded rice. In: Proceedings of the Symposium on Weed Management. Bogor, Indonesia. BIOTROP Special Publication 38:115-129.

Hill, J. E., S. R. Roberts, D. M. Brandon, S. C. Scardaci, J. F. Williams, C. M. Wick, W. M. Canevari, and B. L. Weir. Rice Production in California. 1992. UC Div. of Agric. and Nat. Res. Publication 21498, 22 p.

Hill, J. E., S. C. Scardaci, S. R. Roberts, J. Tiedemann, and J. F. Williams. 1991. Rice Irrigation Systems for Tailwater Management. UC Div. of Agric. and Nat. Res. Publication 21490. 14 p.

Hill, J. E., and M. L. Peterson. 1981. Rice and rice straw production in California. p. 7-11. In Agricultural residue management: A focus on rice straw. A report of the Residue

Management Task Force of the University of California, Davis, CA.

International Rice Research Institute. 1993. 1993-1995 IRRI Rice Almanac, International Rice Research Institute, P.O. Box 933, Manila, Philippines. p. 62

International Rice Research Institute. 1989. IRRI Toward 2000 and Beyond. International Rice Research Institute, P.O. Box 933, Manila, Philippines.

Roberts, S. R., J. E. Hill, D. M. Brandon, B. C. Miller, S. C. Scardaci, C. M. Wick, and J. F. Williams. 1993. Biological yield and harvest index in rice: Nitrogen response in tall and semidwarf cultivars. J. Prod. Agriculture. In press.

University of California. 1981. Agricultural residue management: A focus on rice straw. A report of the Residue Management Task Force of the University of California, Davis. 164 p.

University of California. 1992. Maintaining the competitive edge in California's rice industry. University of California Agricultural Issues Center, Davis, CA. 50 p.

Willson, J. H. 1979. Rice in California. p. 20-40. In: J. H. Willson (ed.) Rice in California. Butte County Rice Growers Association, Richvale, CA.

Table 1. Water holding times and performance goals for molinate (a) and thiobencarb (b).

	Post Application Holding Period and Restrictions	Maximum Peak Concentrations (ppb) Sacramento River		Maximum Peak Concentrations (ppb) Agricultural Drains
a) Molinate				
1983	. 4 days	--		--
1984	. 8 days	20		90
1986	. 8 days - triggered to 12 days when Sacramento river exceeded 13.6	20		90
1987	. 12 days	20		90
1988	. 12 days	20		90
	. volume release restrictions			
1989	. 14 days - conventional system	20		90
	. 12 days - recirculating system			
	. volume release restrictions			
1990	. 19 days - conventional system	20		30*
	. 12 days - recirculating system, two or more growers only			
1991	. no change	20		20*
1992	. no change	20		20*
b) Thiobencarb				
		Primary	Secondary	
1983	. 6 days	10	1	24
1984	. 6 days	10	1	24
	. sale limited to 100,000 acres			
1985	. 6 days	10	1	24
	. sale limited to 100,000 acres			
1986	. 30 days	10	1	24
	. sale limited to 100,000 acres			
1987	. 30 days - conventional system	10	1	24
	. 14 days - recirculating and ponding			
	. increased sale to 110,000 acres			
1988	. 30 days - conventional system	10	1	24
	. 14 days recirculating and ponding			
	. sale limited to 100,000 acres			
1989	. 30 days - conventional system	10	1	24
	. 14 days - recirculating and ponding			
	. sale limited to 110,000 acres			
1990	. 30 days - conventional system	10	1	3.0*
	. 14 days - recirculating and ponding			
	. sale limited to 100,000 acres			
1991	. no change	10	1	1.5*
1992	. no change	10	1	1.5*

*Performance goals established by Regional Water Quality Control Board apply to all waters designated as fresh water habitat.

Table 2. Rice straw burning reduction act (AB 1378) of 1991.

Year	% Acres eligible to burn
1992	90
1993	80
1994	70
1995	60
1996	50
1997	38
1998	25
1999	25
2000	safe harbor

Table 3. Estimated water use by rice.[1]

Source	a-ft a^{-1}
Evapotranspiration	3.0
Outflow	1.5
Percolation	1.5
Total	6.0

[1]Rice water use in the Sacramento Valley (unpublished report, J.F. Williams).

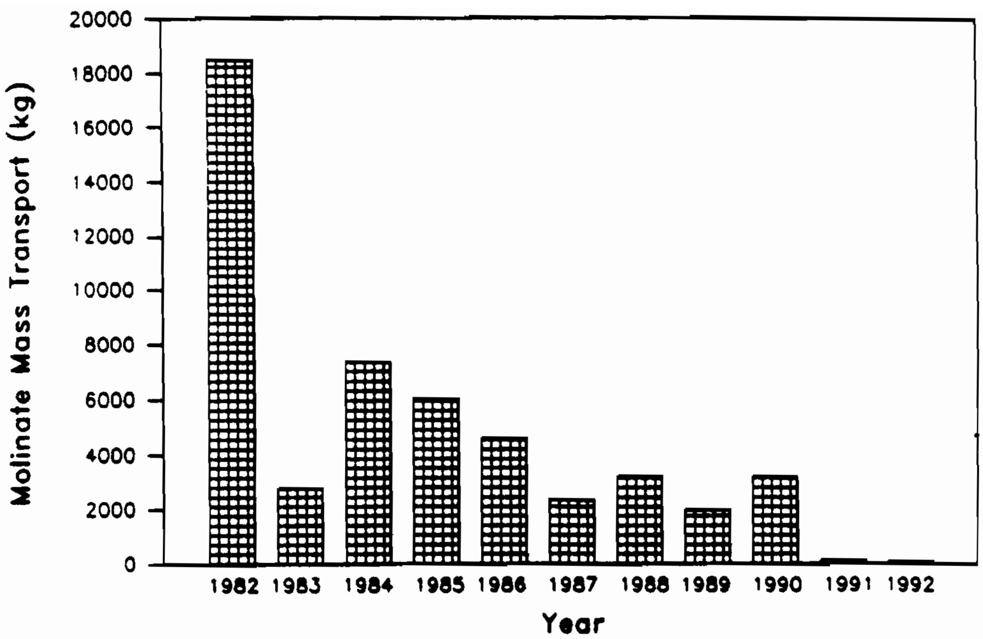

Fig. 1. Total annual mass transport of molinate in the Sacramento river past the city of Sacramento, California.

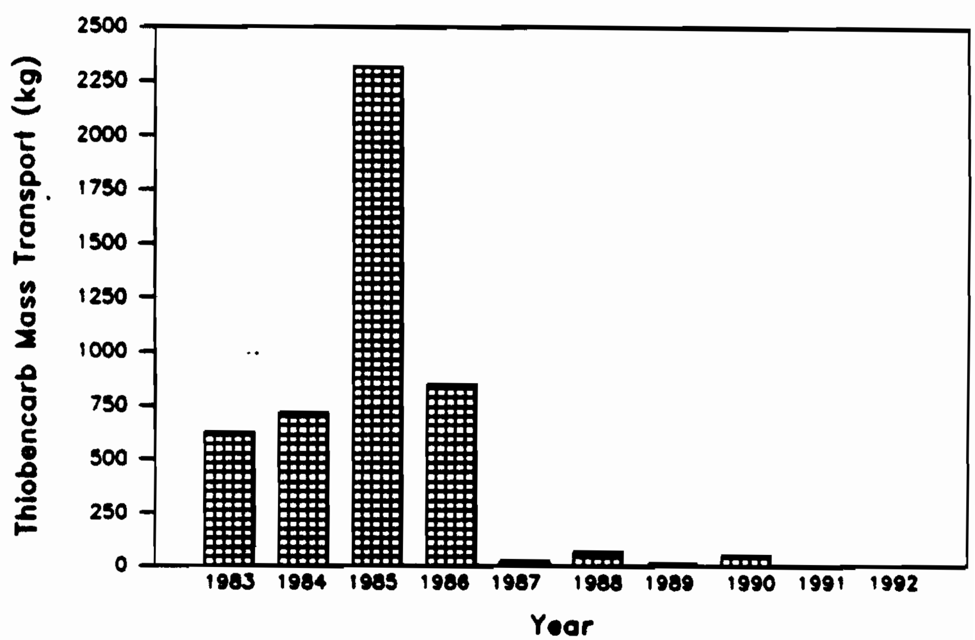

Fig. 2. Total annual mass transport of thiobencarb in the Sacramento River past the city of Sacramento, California.

SUSTAINABLE COTTON PRODUCTION THROUGH PROACTIVE MANAGEMENT

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ABSTRACT

Cotton is the most widely planted annual field crop in California. The cultural philosophies and management practices employed in cotton production today are radically different than those practiced only ten years ago. The changes in cultural practices and improved management have contributed to a statewide lint yield increase of 32 pounds per acre during this past decade. Major changes and programs have occurred in the areas of pest management, irrigation scheduling and plant monitoring for plant growth regulators, fertility and crop termination.

The adoption of these cultural changes is the result of an extensive research and extension effort to develop solutions to current and potential production limitations. From networking with industry and producers, the University of California cotton workgroup has taken a proactive approach to defining researchable priorities. The success of this applied, proactive approach has helped California cotton growers sustain an economically viable production system.

CALIFORNIA'S SHIFTING CROPPING PATTERN'S

BY
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Introduction

Thank you for inviting me to the California Plant and Soil Conference. I would like to discuss with you some changes that have occurred in California's agriculture in the last two decades and then finally conclude with some opinions about the future.

Before going to the specifics I would like to generalize about California's agriculture. While there trends are "old stuff" to most of us here, they help me get a perspective of where we are coming from.

California's Farm Sector

Farm Income- California's farm income has grown from $4.5 Billion in 1970 to $18.2 Billion in 1992. This is a 304 percent growth or a 13.8 percent annual change for the past 22 years. Even compensating for inflation this is a strong growth rate.

Number of Ranches- In 1900 there were 71 thousand farms in the state and by 1992 there were 81 thousand. After almost a century we are almost back to where we started from.. Of course, there have been some changes over the decades in between 1900 and 1990.

The Land Basins- California growers are using less land to grow crops than they did forty years ago. In 1950, some 38 million acres were used for agricultural purposes. By 1992, There was 29.8 million acres used in agriculture.

Inputs Used- To produce the $18 Billion income growers spend $12 to $13 Billion annually producing agricultural products.
In 1991 California farmers spent: $7.5 Billion for seed, feed and replacement livestock, other expenditures varied by class. (See data on slide).

Income Sources- While there has been publicity about California qualifying to have "America's Dairyland" on our license plates, about 70 percent of the state's farm income comes from crops rather than the animal sector. In 1970 about $2.7 Billion came from crops grown in the Golden Bear State. By 1992, crops contributed $13.1 Billion. There has been an a 16 percent annual increase in California's crop income for the past two decades. That is a fairly respectable rate of growth.

California's Crop Section

California has four fairly well defined crop sectors. They are field crops, fruit and nuts, vegetables and melons and nursery and floral products.

Field Crops- These crops include cotton, the grains, rice, beans sugar beets, potatoes, hay and the seed crops. From the time of the "49ER's" to about 1900 wheat was the leading field crop. the state average wheat yield in 1900 was 12.5 bushel per acre (.375 Tons). Barley replaced what as the leading field crop in about 1905.

In 1970 there were 6.1 million acres of field crops grown in the state. By 1992, there were 4.7 million acres grown. This is a 22 percent decline, or a decrease in acreage of about one percent per year. Incomes generated by these crops vary form year to year, But in recent times have been about $3.0 Billion annually.

These crops have shifted to the production acres of highest yields. For trivia, there were three million acres of wheat grown in the state in 1888. In 1992 there were 483,000 acres of wheat in our state. Field crops production often changes rapidly depending on prices and weather . Primary production are the Sacramento and San Joaquin Valleys. Crops in a decline mode appear to be Barley, Potatoes, Sugar beets and Flax.

Fruit and Nuts- These crops have increased rapidly in California. From 1970 to 1992 acreage of California fruit and nut crops increased from 1.3 million acres to 2.1 million acres. This is a growth rate of over 2.5 percent per year. Fruit and nut income has shown over a five fold change in grower returns during the 1970-1992 period. Of course, it must be recalled that this has been an unprecedented growth period for grapes. (Central Valley, Central Coast) and almond acreage's shifting from northern California to the south San Joaquin Valley.

Vegetables and Melons- Acreage's of these crops has increased slightly in the last 20 plus years. During the 1970- 1992 period some acreage shifting was noted; fall and spring lettuce to the San Joaquin Valley, processing tomatoes, once a northern California crop, are now grown throughout the central valley. Although acreage has remained fairly stable, grower's incomes from vegetables has increased greatly. By 1992 these crops returned growers $3.7 Billion. This is 362 percent more than California vegetable growers received in 1970. Grower incomes have increased 16. 0 percent annually since 1970.

Floral and Nursery Crops- These crops are grown in - doors, out-doors, under glass and in pots and without pots. Thus, acreage's grown are difficult to estimate. Floral and nursery crop acreage's have been the fastest increasing crop area of all the crops.

In 1970 about $200 million of these crops were sold by California growers. By 1992 these crops returned $1.9 Billion to growers. This is a growth of 850 percent or 38 percent per year for 22 years.

Comparable data are difficult to develop because of the reporting techniques. A U.S. Department of Agriculture study using 1987 Census data found that over 135 thousand acres of bedding plants bulbs, out flowers, nursery plants sod farms, flower seeds, foliage plants and bedding plants were grown in California (See Slide).

Most of these crops have been grown in coastal regions, but there has been an increasing acreage in the central valley. (See Slides for shifting acreage's of these crops).

The Future:

I always like talking about the future because there are few data that can be used to dispute my *facts.*

Hardly a week goes by when we do not hear about "California Basking." Even more frequently California agriculture is bashed. We destroy the environment, we use water intended for fish and the allegations go on.

Maybe there are some positive things about California agriculture. In this context I would like to discuss agriculture's future relative to SWOT: Strengths, Weaknesses Opportunities, Threats.

Strengths-

California is a world supplier of many crops. There is a wide diversity of crops grown.

Agriculture employs 10 percent of the people in the state. California produces 50 percent of the nation's fruit and vegetables.

Most crops have fairly high yields relative to other states or nations. There has been a shift to the production of higher value crops.

Nursery crop production has grown and is expected to continue its growth.

Many of our production problems have been defined while other states and countries are not sure if they have a problem.

Weaknesses:

Clearly California agricultural has some vulnerable sides. Among these are:

- *Water Availability and Quality.*
- *Environmental Concerns.*
- *Compatibility of Urban Encroachment with Agricultural Production.*
- *Changes in the Comparative Advantage in the Production of some Crops.*

Opportunities

Despite all of the publicity and criticisms agriculture produces food and fiber for people. As the world becomes more inter-related agricultural products will be grown where they grow best. These factors should provide some opportunities for California's major industry.

- *People will continue to eat and, thus, agriculture will be needed*
- *As international trade liberalizes production shifts to those areas with the greatest comparative advantage. California may well become an even more important world food supplier.*
- *California growers have always been rapid adjusters to new technology. This will be even more important in the future. There will be a continual need to improve yields and product quality to maintain the competitive edge of a world leader.*

Threats

As always a world's leadership position in agriculture will be challenged by other areas and other nations. Some of the threats will be:

- *Having adequate water and maintaining its quality.*
- *Compatibility of agriculture with urban development.*
- *Producing wholesome safe food supply.*
- *Controlling pests and plant diseases.*
- *Improving yields to maintain a comparative advantage for world production.*
- *Imports-especially cut flowers and floral products.*

SOIL MICROBIAL BIOMASS AND ORGANIC MATTER MANAGEMENT FOR SUSTAINING SOIL FERTILITY

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Introduction

A fertile soil is a living soil. It is a habitat for many types of macro- (insects, worms, etc.) and microorganisms (bacteria, fungi, etc.). Soil microorganisms influence and are influenced by the physical and chemical properties of the soil habitat. A major function of soil microorganisms or microbial biomass is the conversion of carbon (C) in organic residues to carbon dioxide (CO_2), new microbial tissue, and the formation of various metabolic residues. Thus they are an important component of soil organic matter. The links between organic matter and microbial biomass also directly affect the availability of nitrogen (N)and other macronutrients required by crop plants.

Soil organic matter (SOM) is not a homogenous component of soils. A number of different forms of SOM exist in soils of which the humic fraction or humus comprises the largest proportion. The beneficial contributions of humus to soil properties and fertility are well known. Routine organic matter management will affect this fraction of SOM, although changes will occur slowly (within years) in comparison to the microbial fraction which responds rapidly (within hours) to added organic residues. The quantity, quality, and placement of organic matter additions to soil directly affect all fractions of SOM and these general effects must be known in order to maximize nutrient availability and conservation.

Modern agricultural soil management practices often do not fully rely on the potential of soil microbial processes for maintaining or enhancing nutrient availability to crops. The significant exception is the microbial conversion of fertilizer ammonium-N to nitrate nitrogen (nitrification) and N fixation by leguminous plants. Soil management practices such as tillage, fertilization, and pesticide applications directly affect the microbial biomass both negatively and positively.

Soil and crop management practices that consider soil organic matter management and related biological components appear to be the best way to provide the resilience or buffering capacity needed to resist changes caused by human and natural factors. Effective soil fertility management with organic residues or amendments requires some understanding of microbial processes and activity as we are "feeding" this SOM component as well as a crop. The use of cover cropping practices increases reliance on microbial processes in agricultural soils. Informed organic matter management practices can improve the effectiveness and cost efficiency of other production inputs (i.e. fertilizers, water) and are a critical components of sustainable soil management. In this paper I will limit the discussion of organic matter management and microorganisms to general aspects regarding nutrients and soil structure.

Soil Organic Matter

A large amount of emphasis has been placed on the properties and quantity of SOM. Some researchers have noted that plants can be grown in the absence of humus or SOM, therefore SOM can not be considered to be essential to plant growth. The indirect influences of SOM on physical, chemical, and biological properties are universally recognized as:

- Darker color facilitates soil warming in temperate regions
- Improves soil aggregation, pore size, aeration, drainage, and water-holding capacity
- Acts as a reservoir and source for plant nutrients, contributes to cation exchange, and chelation of micronutrients
- Enhances the pH buffering capacity

Soil organic matter (SOM) does not accumulate indefinitely in well-drained soils. An equilibrium level is attained as controlled by the soil-forming factors of climate, topography, vegetation and organisms, parent material, and time. Most often SOM levels decline when soils are first placed under cultivation (notable exceptions are likely irrigated and fertilized desert soils). Many agricultural practices accelerate decomposition and mineralization of SOM such as:

- Cultivation - improves the aeration and moisture status, thereby increasing microbial activity
- Irrigation - improves the moisture status, increasing microbial activity
- Liming - increases activity of macrofauna and, perhaps actinomycetes (which are thought to be more effective decomposers); making some micro-metals insoluble which are important in stabilizing humic substances
- Green manuring - greatly increases the numbers and activities of microorganisms

Any management system which increases the total carbon (C) addition per unit area per year can increase the size of the SOM fraction in soils. Managing crops and soils solely for increasing the total amount of SOM may be desirable, but should not be the goal of organic matter management. We should recognize that SOM is actually a mixture of living and dead material, simple and complex compounds, which are susceptible and resistant to decomposition. These varying perspectives/definitions/concepts can be described by physical and chemical fractionation of the SOM component.

An approach which I favor (Figure 1) conceptually divides SOM or soil organic C into:

- An active (labile) fraction - consisting of the living microbial biomass, its metabolic products, and easily decomposable residues
- A slow fraction - that may be physically (i.e. within soil aggregates and/or chemically protected (i.e. biologically resistant)
- A passive/resistant fraction - which is chemically resistant and may be physically protected

These fractions have been defined through various analytical approaches based on physical, chemical, or biochemical characteristics

The soil microbial biomass represents only a small portion of the total soil organic matter content. The microbial biomass may comprise 1-5% of the total soil C (SOM ~ (1.72 x C), 1-4% of the total N, 0.5-12% of the total P, and 1.5-3.0% of the total S in soil. While these proportions may seem small the rapid growth and death cycles (often just days) of the biomass amplify their potential impact on nutrient availability. Estimates for the pool of N held in microbial biomass in soils at any given time range from 36-1100 kg ha^{-1} (32-980 lbs N $acre^{-1}$). Thus the microbial biomass can comprise a substantial pool of nutrients.

The dominant free-living components of the soil biota are the microflora, micro-, and macrofauna. Within each of these living components, there exists a broad range of physical (morphological) and physiological (biochemical) characteristics:

- Bacteria - heterotrophic and autotrophic
- Fungi - heterotrophs, includes mycorrhizae associated with the roots of many crops
- Actinomycetes - subgroup of bacteria, heterotrophic
- Protozoans - heterotrophic, feed on dead organic matter and predation of bacteria
- Metazoans - or macrofauna, nematodes, worms, mites, spiders, insects; most prey on other microorganisms and thus have a role in decomposition

Microbial Processes

Decomposition

Organic residues differ in their chemical composition such that young herbaceous green matter will have higher protein and carbohydrate content than a well rotted compost which may have a higher lignin and humic acid content. Carbohydrates, amino acids, and proteins are easily digested by soil microorganisms. More complex molecules such as hemicellulose, phenolics, and lignin (woody molecules) are more resistant to decomposition and can increase the microbial demand for soil N in order to digest such materials. Soil humus forms by chemical processes from the products of microbial decomposition and, as mentioned previously, is quite resistant to decomposition.

The more active SOM fractions consist of easily decomposable residues, decomposition by-products, and the living microbial biomass. Soils with a significant active organic fraction will have a significant amount of microbial cell residues and metabolites are dispersed in water films bathing soil particles and roots of crops. Microbial decomposition leads to the formation of many transitory organic compounds possibly containing N, phosphorus, sulfur, and other nutrients which could be absorbed by roots. The rhizosphere of plants is a zone of intense microbial activity and some crop absorption of these metabolic products will likely occur.

Mineralization

Much emphasis is placed on the importance of N mineralization as a key element in managing N from organic inputs. The mineralization of organic N to NH_4-N is a key process leading to enhanced availability of N to the microbial biomass. Indeed "the bugs go to dinner first" such that increased microbial growth is supported by increased absorption of mineralized N (immobilization) which from a cropping viewpoint is considered to be negative.

Much of the conventional thought concerning N nutrition of crop plants centers on the importance of the quantity of NO_3-N available in the soil solution. Most of our crop varieties are bred in soil environments where NO_3 is in large supply. As it is almost completely soluble in soil water and the inevitable product of microbial processes it is considered a very available form. However excessive nitrification or nitrate content in soils can also lead to lowered crop utilization efficiencies if leaching or denitrification potentials exist. The uptake of soil N by the microbial biomass may also conserve N by placing it in this "protected", yet active fraction. The formation of NH_4 during microbial decomposition or the addition of NH_4 containing fertilizers provides a key requirement to bacterial chemoautotrophs that carry out nitrification. Limited availability of NH_4 will limit the amount of NO_3 formed with time.

Soil microorganisms are also intimately involved in the availability of soil phosphorus (P) and sulfur (S). They participate in the solubilization of inorganic forms and the mineralization of organic forms and may have a negative affect on soil solution levels during periods of high growth and activity. Microbial uptake of soil P may be advantageous as it "protects it" from precipitation and fixation reactions with soil minerals. In many soils mineralization of organic P and S can potentially supply the total needs of crops.

Aggregate formation and stabilization

Soil structure is a major component of soil fertility. Soil structure and its stability is the determinant of soil tilth. Soil C is believed to be an important component of soil quality because of its influence on aggregate stability which directly affects water infiltration, retention, and runoff. The resistance of aggregates to physical breakdown due to tillage or water is a critical requirement for sustained soil fertility.

. Microbial biomass and activity are critical to the formation and stability of particle aggregates. Microbial synthesized polysacharrides form the sticky binding agent. While these binding agents may eventually be mineralized themselves, continuous microbial activities assure the persistence of significant particle aggregation. The hyphae of fungi which bridge and bind particles is another aggregate forming agent.

Organic matter quality

The largest fraction of organic matter (or carbon) entering the soil is that contributed by plant residues. Often ignored is the significant mass of C entering soil via root growth, death, and decomposition, which can make up to 50% of the total C photosynthetically fixed. Plants contain C as 15-60% cellulose, 10-30% hemicellulose, 5-30% lignin, and 2-15% protein. Soluble substances (sugars, amino and other organic acids may constitute up to 10%. Roots of annual crops have more a resistant composition (i.e. hemicellulose, lignins) than the herbaceous tops. The soluble substances are readily leached from the residues and are quickly utilized by soil organisms. This distribution of chemical constituents will vary according to the plant species, nutrition, and age.

Animal manures will contain similar materials, but due to previous digestion, the proportions may vary there may be Cattle manures contain more resistant materials (i.e. lignin), while poultry manures will contain higher amounts of urea and other volatile and easily decomposed organic compounds. Composted wastes will have high amounts of resistant organic matter including humic materials.

Given the range of chemical composition of various organic residues, it is apparent that these materials will have varying qualities and impacts on microbial processes. Residue quality in relation to nutrient management might be defined from two perspectives; the quality parameters favoring nutrient availability (i.e. rapid mineralization) and those favoring nutrient (particularly N) conservation.

Managing the active fraction of SOM

Historically, approaches to regulating crop nutrient availability through organic matter management have involved: manipulation of existing soil organic matter through tillage or soil drainage; crop residue placement on or in soil qnd burning to enhance management operations; production of green manure, cover, and sod crops; and amendment with animal wastes and composts. These practices all have significant direct or indirect impacts on the active SOM fraction, though insignificant short-term effects on total SOM. Management which directly affects the quantity, quality, and placement of organic matter inputs also controls the availability of energy (or food) to the soil microbial biomass. It is then possible to conceive of practices that recognize the potential for intentionally managing the active fraction for differing fertility objectives.

Increasing the total C addition per unit area per year can increase the size and potential of the active fraction. However the quality of the organic matter input must be considered in fulfilling such an objective. The degree of soil physical disturbance (tillage) associated with management systems influence the habitat for biological activity through effects on aeration, soil bulk density, aggregation, and access to substrates. Alteration of the chemical status of soils with fertilizer and amendment inputs can also be used to manipulate active SOM. Using these tools with an expanded view of SOM and organic residue quality will lead to more informed soil fertility management practices.

Organic matter management can be implemented with varying fertility goals or objectives. High nitrogen content green manures, which are digested rapidly by microbes can provide a significant portion of crop N requirements. However, the impact of this N input will be dependent on a number of abiotic soil factors, other fertility inputs, and the specific crop(s). Incorporation of low-lignin content cover crops or green manures can decrease SOM levels due to their "hyper-stimulation" of microbial activity which can increase mineralization of native SOM. An organic matter input like a mature compost can be combined with the use of N fertilizer so that some portion of the fertilizer N is absorbed and temporarily immobilized by microbial heterotrophs. Release of that N will occur at a slower rate following the initial partial immobilization, possibly more in synchrony with plant demand.

Conversely, enhancing the immobilization potential of the microbial biomass at key times of the year can reduce soil nitrate and nitrification potential, thus leading to N conservation. The incorporation of biologically resistant organic residues at the end of a cropping season can deprive the nitrifying bacteria of available NH_4-N, thus limiting NO_3-N available for leaching or denitrifiication loss from soil. Uptake and assimilation of phosphorus (P) by cover crops or crops can improve the availability of P following soil incorporation due to microbial absorption and subsequent release.

Tillage and moisture management could be another approach to maximizing the potential of microbial immobilization and mineralization processes to provide crop nutrition. Tillage, which disrupts the microbial biomass and soil aggregates, increases decomposition and mineralization. Drying of soil, followed by rewetting, can also result in significant increases in decomposition and mineralization of active fraction SOM. The coordination of tillage for weed control, applications of fertilizers/organic amendments, and water management might be another approach to regulating microbial processes to enhance soil and fertilizer nutrient utilization efficiency by crops.

Developing more informed OM management practices will require new ways of analyzing the fertility status of soil. While there will be no replacement of most standard soil analysis systems, a grower must consider the soil as a system and specifically a habitat for microorganisms (Figure 2). In order to maximize the biological potential of soil the requirements of the biota must be optimized. Monitoring of soil structure, oxygenation, soluble C, and some indirect assessments of the microbial biomass or potential could included in the standard analytical methods. A part of my research effort compares various methods of assessing the interaction of organic residue quality and soil microbial processes. We have no conclusions yet, but believe that there will be some utility to assessment of microbial and/or active fraction potential in soils.

Informed SOM Management Practices

A critical foundation of sustainable soil management systems is acknowledgment and enhancement of the microbial potential of soils. Such systems represent an approach which attempts to optimize the recycling and conservation of materials/nutrients, while maximizing the use-efficiency of external resources. A number of the specific approaches will involve the partial or total substitution of biologically fixed N from legume crops and recycling of various organic residues for fertilizer N. Thus, in terms of nutrient management these systems will rely more on C cycle dynamics (i.e. decomposition and mineralization) than inorganic fertilizer dominated systems. Crop and nutrient management practices might better manage N immobilization and mineralization in relation to crop requirements for N. Thus N could be better conserved in the active SOM fraction and, to a degree, protected from leaching and denitrification.

Tillage can be considered to be an important technique for managing stored soil nutrients. Although not a simple solution due to differences in soils, climate, crops and macronutrient in question, it should be possible to devise management systems which use tillage to optimize the synchrony of crop needs, soil nutrient release or storage. Achieving such synchrony is a complicated task even when only considering one element such as nitrogen (N).

Approaches to organic matter management should also integrate the use of differing organic residues and fertilizers. By supplying diverse food/energy sources to the soil microbial complex and recognizing quality-quantity interactions, we could ensure resilient soil systems. Enhancing the microbial potential of soils (within economic and ecological limits) and maximizing the general benefits of SOM can potentially enhance the efficient use of any other fertility or crop nutrition input. Such practices are the foundation of sustainable soil fertility management.

**This paper is based largely on an article to be published in the journal of Practical Winery and Vineyard*

Figure 1
A conceptual model of soil organic matter
and decomposition of organic residues

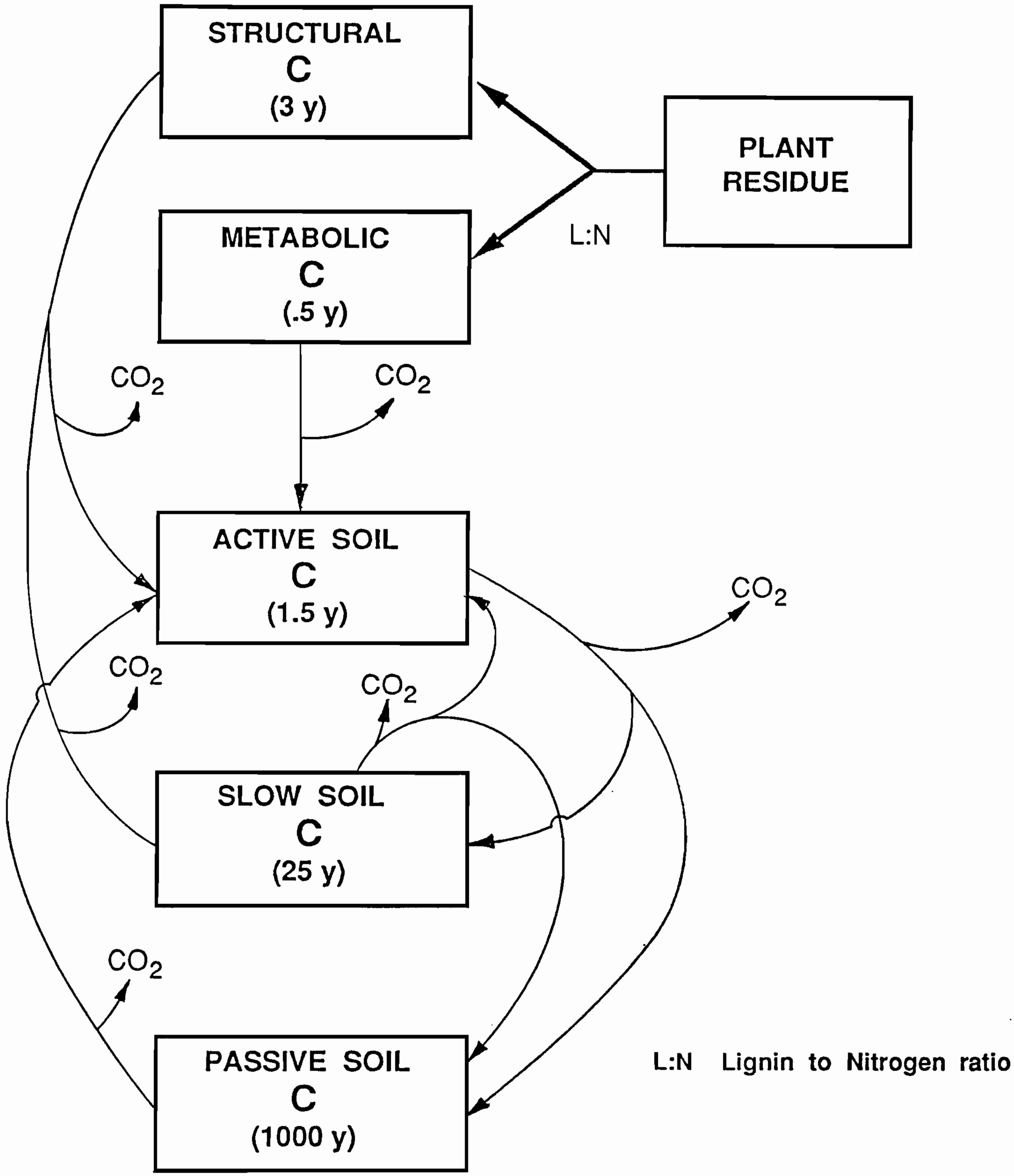
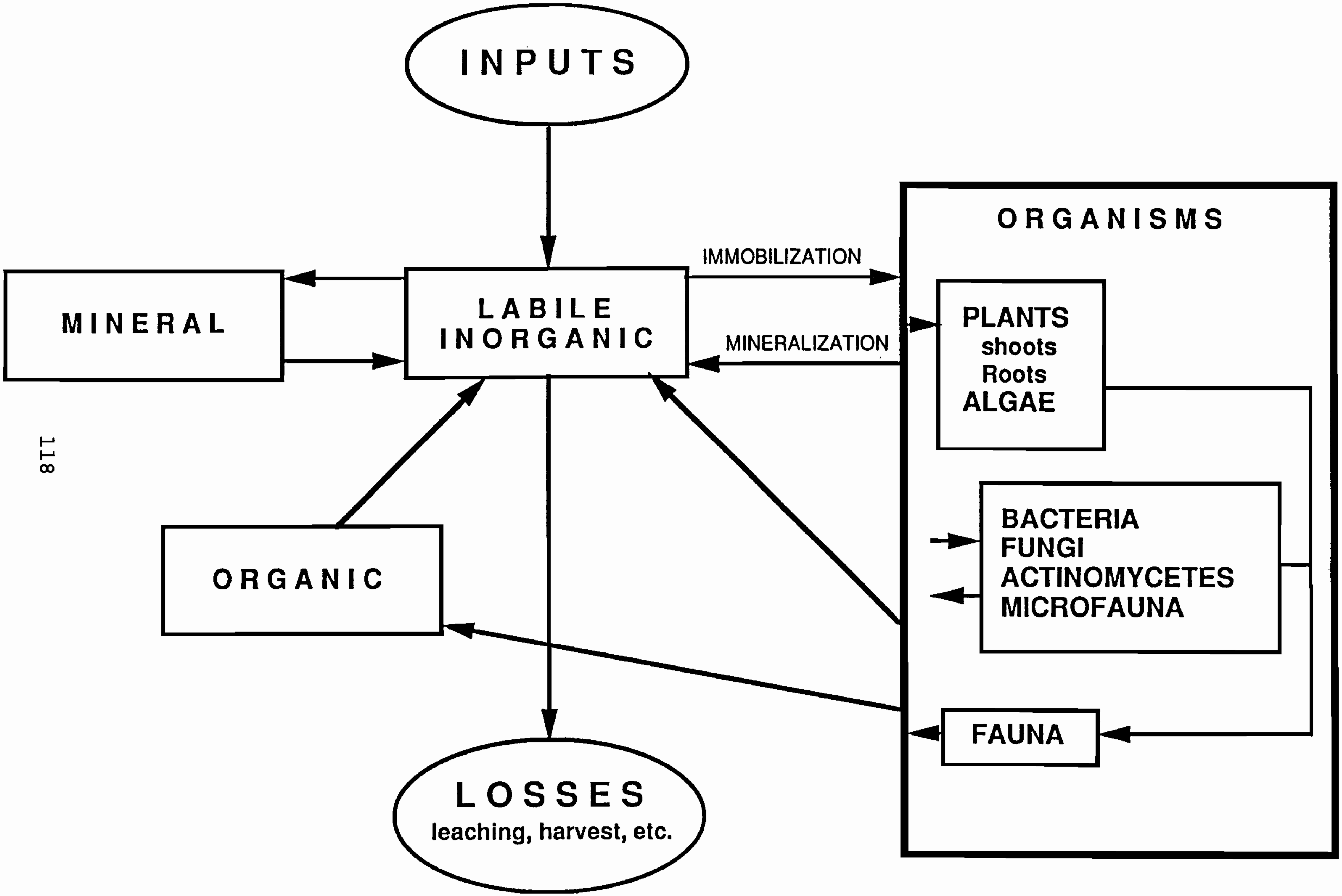


Figure 2

A conceptual model of the soil-crop system



CALIFORNIA MOBILE IRRIGATION LABS

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ABSTRACT

Mobile Irrigation Laboratories have been serving agricultural water users throughout California for the past 10 years. These services are provided by a variety of public agencies, including Resource Conservation Districts and irrigation districts often with funding assistance from the California Department of Water Resources and local water districts. Although individual programs may vary in scope, their main emphasis is to provide direct technical assistance to improve on-farm water management practices.

INTRODUCTION

Agricultural irrigation is the major use of water in California, accounting for approximately 85 percent of the water consumed by all users. Water is becoming an increasingly scarce resource in California as more and more interests compete for a limited amount of water. Therefore, it is in the best interest of all water users to use these limited supplies as efficiently as possible. If the efficiency of irrigation can be increased, there can be a corresponding decrease in demand for water. With increased public attention focused on agricultural water use, visible pro-active programs that promote agricultural water conservation are especially prudent policies.

Irrigation water management programs are available in many areas of California. These services are provided by a variety of public agencies, but most notably by Mobile Irrigation Laboratories, or Mobile Labs. Originating in Texas in the early 1980s, the concept of the mobile labs was adopted by the California Department of Water Resources (DWR) in 1983 to assist growers in utilizing another DWR program, the California Irrigation Management Information System (CIMIS). The CIMIS network of computerized weather stations provides reference evapotranspiration (ETo) for use in irrigation scheduling. ETo, factored with a crop coefficient (Kc), can provide an estimate of crop water use. This information can help growers in planning irrigations. But this estimation of crop water requirements is only part of the irrigation scheduling process. Besides knowing when to irrigate and how much water to apply in order to best meet the irrigation demand, the farmer must also know the water application rate and the uniformity of its application. Often these important factors are unknown. Irrigation system evaluations can help growers get a better handle managing their irrigations.

PROGRAM GOALS

Typical on-farm irrigation efficiencies are lower than the potential for well designed and managed irrigation systems (Burt, et al., 1993, and Pitts, et al., 1993). The uniformity of water applications and the timing and planning of irrigation amounts are key to improving the efficiency of irrigations.

Irrigation Water Management programs such as Mobile Irrigation Labs provide direct technical assistance to quantify irrigation system performance and, where appropriate, provide recommendations to improve irrigation practices.

The objectives of these programs are generally to:

- Evaluate irrigation systems for uniformity of applied water
- Quantify irrigation system performance
- Estimate the irrigation efficiency for a single irrigation event or for the entire season (when possible)
- Identify any factors limiting irrigation system performance
- Recommend feasible practices to improve irrigation system performance
- Provide direct technical assistance in irrigation water management
- Promote efficient agricultural water use and improved irrigation strategies

Specific programs may include technology transfer to growers interested in improved methods of irrigation scheduling. These technology transfer programs are not intended to compete with private sector irrigation management services. However, it is possible that the increased understanding of water management developed by growers participating in such programs could lead to an increased demand for private sector irrigation management services.

Mobile lab services are available to water users at no cost. However, the existing programs are generally limited to the geographic service areas of the providers shown in Figure 1.

FIELD EVALUATIONS

Mobile Labs and similar programs are equipped to evaluate all types of irrigation systems. Irrigation specialists evaluate farm and large landscape irrigation systems to determine the effectiveness of irrigation practices and make recommendations as to how the efficiency of irrigations may be improved.

Mobile lab teams work around normal farming schedules and require only a minimal amount of the grower's time. Each evaluation is summarized in a report which is personally delivered and explained to the participant. Each report contains useful information pertinent to the irrigation system evaluated including:

- Application rate of water applied
- Distribution uniformity of water applied
- The factors responsible for non-uniform water application
- Analysis of any site specific irrigation problem
- Tips on irrigation planning

CALIFORNIA MOBILE LABS
AND SIMILAR SERVICES

1. Los Banos Resource Conservation District
   (209) 826-5770
2. Pajaro Valley Water Management Agency
   (408) 722-9292
3. Monterey County Water Resources Agency
   (408) 755-4860
4. Kings River Conservation District
   (209) 237-5567
5. Pond-Shafter-Wasco Resource Conservation District
   (805) 861-4129
6. Cachuma Resource Conservation District
   (805) 937-6363
7. Ventura County Resource Conservation District
   (805) 386-4685
8. Riverside-Corona Resource Conservation District
   (909) 683-7691
9. San Jacinto Basin Resource Conservation District
   (909) 654-7733
10. Coachella Valley Resource Conservation District
    (619) 347-7658
11. Mission Resource Conservation District
    (619) 728-1332
12. Imperial Irrigation District
    (619) 339-9817

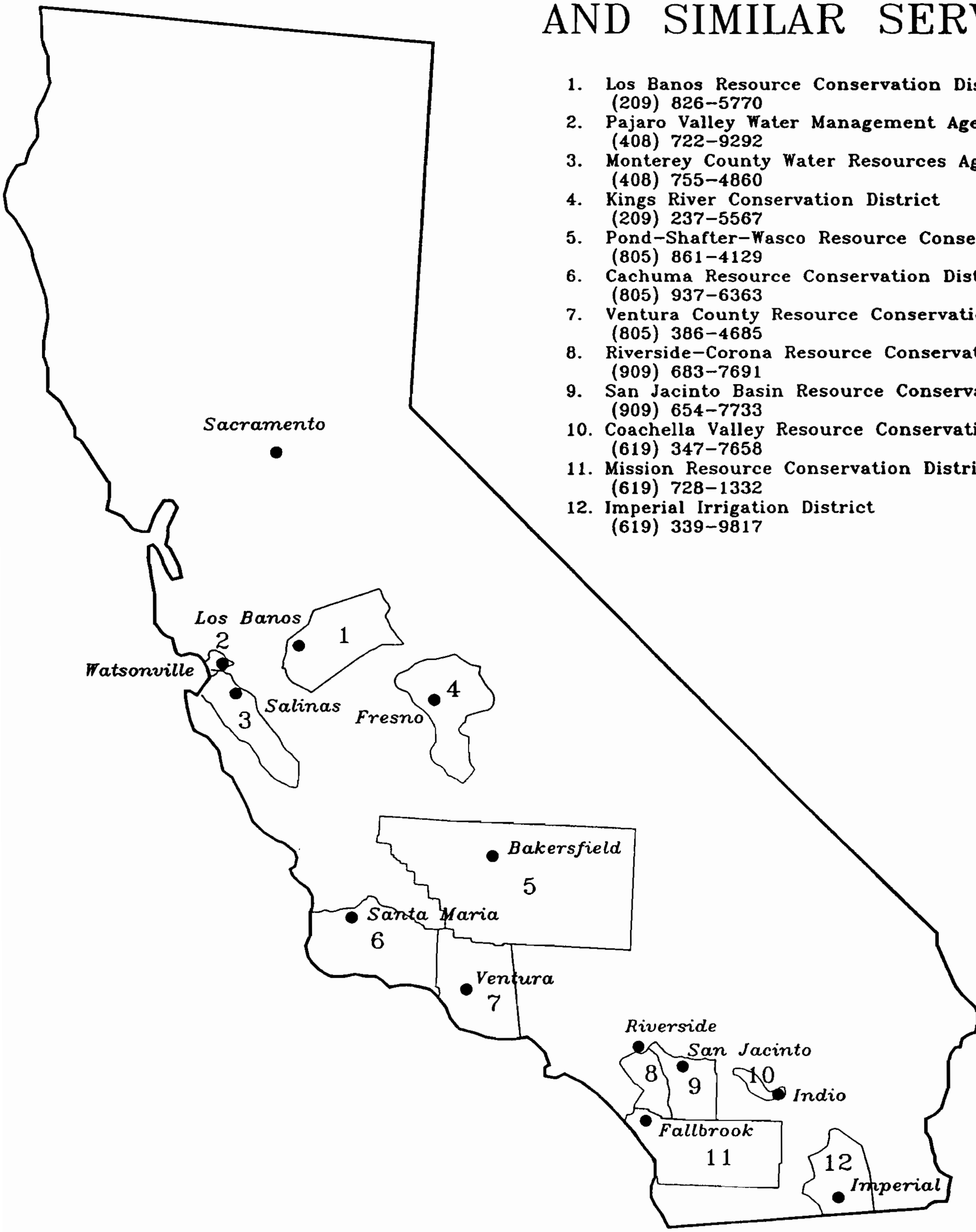


Figure 1. General service areas of Mobile Labs and similar irrigation system evaluation services.

Measures of irrigation performance

Any discussion of water use should make sure that there is consistency in use of terms, to avoid the confusion of using different terms and numbers to describe the same situation.

The performance of an irrigation system can be gauged by measurements of distribution uniformity (DU) and irrigation efficiency (IE).

Distribution uniformity (DU) is a measure of how evenly an irrigation system applies water to all plants in a field.

Distribution uniformity (DU) is defined as:

$$DU = \frac{\text{low } 1/4}{\text{average}}$$

- where the low 1/4 is the average depth of water infiltrated in the 25 percent of the areas receiving the least amount of water and,
- the average is the average depth of water infiltrated in the field.

DU is a ratio of averages that is generally used in planning irrigations to minimize under-irrigation. DU is not a comparison of maximum and minimum water applications. This is an important consideration when applying fertilizers or other chemicals in the irrigation water. A DU of 75 percent can result in a 50 percent difference between the maximum and minimum amounts of water applied throughout a field. When applying chemicals in the irrigation water, higher levels of uniformity are desired. At a 75 percent DU, only chemicals which cause no damage when variations of this magnitude occur, can be used for chemigation. Otherwise higher DUs would be necessary.

If water is not applied evenly, portions of a field may be under-irrigated and/or over-irrigated. If distribution uniformity is low, a field can be irrigated sufficiently only if excessive water is applied to certain areas (Figure 2B).

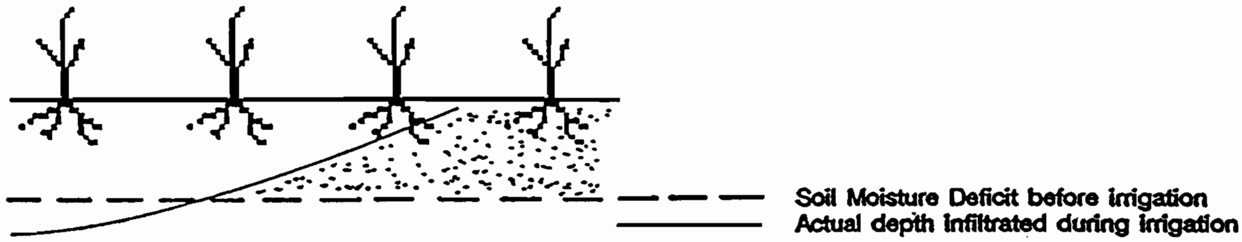
Non-uniform water application is one of the main limitations to achieving high on-farm irrigation efficiencies.

Irrigation efficiency (IE) is a measure of the proportion of water applied that is actually used beneficially. Irrigation efficiency (IE) is defined as:

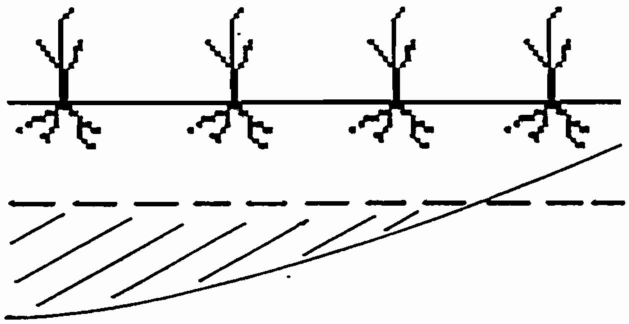
$$IE = \frac{\text{water beneficially used}}{\text{total water applied}}$$

where beneficial uses include water necessary for:
- crop transpiration
- salinity control
- climate control (frost protection and crop cooling)

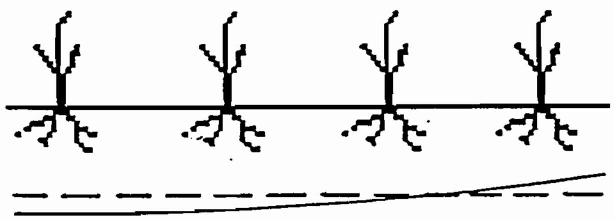
and beneficial uses do not include:
- application losses such as spray drift or uncollected run-off
- evaporation from wet soil surfaces or wet foliage
- deep percolation of water past the root zone (in excess of leaching requirement)



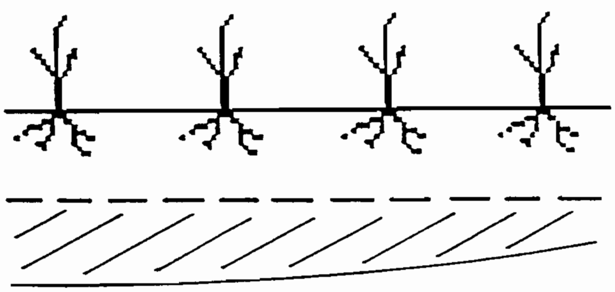
A. Poor DU resulting in under-irrigation (efficient but not effective).



B. Poor DU resulting in adequate irrigation (not efficient but effective).



C. Good DU, adequate irrigation (efficient *and* effective).



D. Good DU, but over-irrigation (not efficient but effective).

Figure 2. Different possible water destinations and resulting irrigation efficiencies.

Estimating IE can be difficult at best because of uncertainties in quantifying actual water destinations. Therefore, many studies limit their scope to studying DU, which may be considered the precursor to IE. Good distribution uniformity (DU) is necessary in order to achieve efficient and effective irrigations. If the amount of beneficially used water is the same as the average amount infiltrated in the low quarter, then the DU would be equal to the IE (not accounting for application losses). The DU may be considered as the maximum potential IE of a properly managed irrigation system if under-irrigation is to be avoided.

Distribution uniformity (DU) is a limiting factor of irrigation efficiency (IE). The level of IE can be greater than the DU, only if there is significant under-irrigation.

However, good DU is no guarantee of good irrigation efficiency. Management (the human factor) plays an important part in irrigation efficiency. For example, if an irrigation system with a 90 percent DU, applies two inches to the "low quarter", but only one inch was needed, the resulting IE would be 45 percent (Figure 2D).

Table 1 indicates a theoretical range of irrigation efficiency of 75 to 90 percent for well designed irrigation systems under best management. Similar systems with just average management have potential efficiencies 15 to 20 percent less. Different authors will use slightly different values as potential IEs, but if the appropriate irrigation system is well designed, it is often the management of an irrigation system that can limit its ultimate efficiency.

Table 1. Potential DUs and IEs for well designed irrigation systems with excellent and average management (Burt, 1992).

Irrigation Method	DU (%) (best)	IE (%) (best)	IE (%) (average)
Linear Move	92	90	70
Furrow	89	88	70
Drip	90	88	65
Hand Move Sprinkler	75	75	60

Range of distribution uniformity

Several projects have attempted to characterize the range of distribution uniformities and irrigation efficiencies of the different irrigation methods.

Without going into detail, these projects have generally shown that for all irrigation methods examined, there is a wide range of system performance and no single irrigation method is necessarily preferable to another.

Table 2 shows the range of distribution uniformities for farm irrigation systems evaluated in the Salinas Valley. The average DU for the various irrigation systems was 67 percent. The average distribution uniformities for the different irrigation methods are not significantly different.

Table 2. Summary of farm irrigation system evaluations performed in the Salinas Valley. (MCWRA Mobile Lab and U.C. Cooperative Extension, 1990-1992)

System Type:	no.	DU (%) min	max	avg
All Systems:	103	27	93	68
Sprinkler	39	41	87	67 a
Linear Move	10	62	88	74 a
Drip (vines)	3	49	93	69 a
Drip Tape (all)	26	27	92	64 a
[berries	13]	27	86	60 a
[row-crop	13]	46	92	68 a
Furrow	25	27	88	66 a

Values followed by the same letter are statistically similar at a 95% confidence level.

It can be seen in Table 2 that all irrigation methods have a wide range of performance and that no one irrigation method is necessarily preferable to another.

The fact that different irrigation methods have similar average levels of uniformity implies that it is the proper selection the design and management of an irrigation system rather than the type of system, that is the key to achieving uniform (and potentially efficient) irrigations.

The limitation of such analyses include the relatively small sample sizes and the non-random selection of survey subjects (ie. those farmers participating in irrigation system evaluations to begin with may be more concerned with irrigation system performance).

In 1987, U.C. Cooperative Extension performed several season long irrigation efficiency evaluations in the Salinas Valley (Schulbach, 1988). Because such evaluations are more detailed than single event evaluations, fewer were performed (precluding any statistical analysis). However, the DUs and IEs estimated on a seasonal basis were similar to those estimated from a single irrigation event.

Table 3 summarizes a survey of the irrigation system evaluations performed by Mobile Irrigation Labs in eight different regions of California. This <u>does</u> show significant differences in the DUs evaluated for the different irrigation methods (Hanson and Bowers, 1992).

Table 3. Summary of statewide irrigation system evaluation results by system type.

System Type	Average DU (%)
Hand Move Sprinkler	62 c
Linear Move / Center Pivot	75 a
Undertree Sprinkler	79 ab
Drip	73 a
Furrow	81 b
Border	84 b

Values followed by the same letter are statistically similar at a 95% confidence level.

Table 4 summarizes the same evaluation results listed in Table 3, but by geographical region rather than by irrigation method (Hanson and Bowers, 1992).

Table 4. Summary of statewide irrigation system evaluation results by region.

Region	Average DU (%)
Salinas	68 b
Ventura	68 b
San Diego	69 b
Cuyama	63 b
Coachella	77 a
Los Banos	81 a
Shafter	76 a
Riverside	80 a

Values followed by the same letter are statistically similar at a 95% confidence level.

Average DUs in the coastal areas are significantly less than in inland areas. This may be attributed to the higher frequency of pressurized irrigation systems in the coastal areas. The advantage of pressurized irrigation systems however, is the ease of control of the depth of water application.

Although furrow systems can have a high level of uniformity, their resulting efficiencies can be low because of their limitation to a relatively large minimum practical application depth, as compared to pressurized irrigation systems.

The values of DU and IE for furrow irrigation systems in coastal areas are generally lower than in inland areas where deeper rooted, less moisture sensitive and lower value crops are grown. This is because it is more difficult to apply small amounts of water uniformly with furrow systems, hence the advantage of pressurized irrigation systems. The vegetable crops characteristic of the coastal areas are of high value and sensitive to moisture stress. The light but frequent irrigations often required by these crops are generally difficult to achieve efficiently, especially with surface irrigation methods.

CONCLUSION

Increasing irrigation efficiency can have the following benefits:

- Reduced water cost resulting from decreased water use
- Lower pumping costs
- Improved or at least equitable crop yields
- Reduced fertilizer costs
- Reduced nutrient leaching
- Maintenance of water quality

As water supplies become more limited, farmers may be faced with several options:

1. "Stretching" water supplies to get the most benefit from a limited amount of water by increasing irrigation efficiency.
2. Switching to less water demanding crops.
3. Reducing irrigated acreage.

Option 1 is clearly the first place to start.

To begin the process of improving irrigation efficiency, the first steps are to quantify irrigation performance and water use. Irrigation evaluation services are available to help with this and should be utilized.

CITATIONS

Burt, C., R. Walker, and S. Styles. 1993. Irrigation system evaluation manual. Produced for the California Department of Water Resources, Office of Water Conservation, by Department of Agricultural Engineering, Cal Poly, San Luis Obispo, CA, 93407, 162 p.

Burt, C. 1992. Efficiency in irrigation. Irrigation Training and Research Center, Cal Poly, San Luis Obispo, CA. 25p.

Hanson B. and W. Bowers. 1992. An analysis of mobile laboratory irrigation system evaluation data. (Report to the State Department of Water Resources, Division of Planning, Agreement No. B-58860.) Department of Land, Air, and Water Resources, University of California, Davis, CA, 95616.

Pitts, P. G. Czarnecki, G. Gilbert, and K. Petersen. 1993. Mobile laboratory for irrigation system evaluations. U.S.D.A. Soil Conservation Service, Santa Maria, CA, 93455, 26p.

Schulbach, K. 1988. Crop water use and irrigation efficiency. Final report, Monterey County Agricultural Extension Service, Salinas, CA, 93901, 17p.

Compost Production and Utilization

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Compost is the end product of the decomposition of organic matter by microbes under controlled conditions. Starting materials for composts may come from agricultural sources (e.g., manures, bedding, crop and processing residues) or non-agricultural sources (e.g., green waste, wood by-products, sewage sludge). There are many composting systems in use and the quality of the management of composting operations can be quite variable. Because of the variability of all of these factors, the suitability of different composts for various agricultural and horticultural applications is also highly variable. High quality composts can improve soils and enhance crop growth. However, poor quality composts may exacerbate problems in some soils, contain phytotoxic or phytopathogenic constituents, or have other disadvantages for certain applications. Understanding the composting process and the nature of composts can help growers evaluate and use composts to maximize their benefits.

Three types of composting are commonly recognized: aerobic, anaerobic and vermicomposting. In aerobic composting, a wide range of aerobic microbes decompose most of the original organic matter and synthesize new organic compounds. Usually high temperatures are generated for an extended time and a large amount of carbon is lost as CO_2; gaseous nitrogen losses may also be significant. In anaerobic systems, anaerobic microbes partially digest, or ferment, the organic matter. Microbial activity and decomposition are not as great as in properly managed aerobic composting systems and temperatures do not become elevated. Anaerobic systems generate many organic acids and other phytotoxic compounds as well as biogas, which contains methane and may be used as an energy source. Anaerobic systems conserve nitrogen and anaerobic compost may be subsequently composted aerobically to improve its agricultural utility. Vermicomposting is an aerobic process in which certain types of earthworms digest organic matter and produce castings, which can be very high quality material. In vermicomposting, temperatures remain at near ambient levels and worms perform best in the 60-85°F temperature range. Worms are sensitive to anaerobic conditions, ammonia, extremes in temperature, and lack of moisture.

The focus of this presentation is aerobic composting, which is the most common composting process for agricultural applications. There are several aerobic composting methods, including turned windrows, aerated static piles, passive static piles or windrows, and aerobic in-vessel systems. In any aerobic system, composting is most rapid when microbial activity is maximized. This is accomplished by using starting materials which have the proper balance of carbon and nitrogen and keeping the material very moist and well oxygenated (see Table 1). If these criteria are met, microbial activity will accelerate and the composting material will heat up rapidly following the construction of the pile or windrow. If the system is properly managed, microbial activity and compost temperatures will stay high (e.g., 130-150°F) for several weeks during this "thermophilic phase" of composting. Usually after two to three months, the compost will begin to cool down slowly to ambient temperatures, even given optimum conditions for microbial activity (e.g., proper amounts of H_2O and O_2). This period of maturation is sometimes called the "curing phase" of composting and is important for many uses of compost.

The aerobic composting process has many benefits. It typically reduces the weight and volume of the starting material by approximately 50%, thus facilitating handling. Composting can transform materials that are unsuitable for direct agricultural land application into a valuable soil amendment. For example, high carbon materials can be blended with high nitrogen materials to produce a compost with a balanced C/N ratio. In addition, the high levels of microbial activity and high temperatures in a compost pile can kill weed seeds and plant and animal pathogens and degrade organic contaminants such as pesticide residues. Composting favors the production of humus, the chemically complex and most stable fraction of organic matter. Finished compost can also contain numerous microbes which serve various beneficial functions in the soil ecosystem, such as suppression of soil borne plant pathogens.

There are also disadvantages to aerobic composting. Composting requires time, labor and equipment and many of the benefits of composting are more difficult to quantify than the costs of compost production. Nitrogen losses during the composting process may be significant; unfortunately, managing composts to maximize nitrogen conservation may have other detrimental effects on the composting process. The "slow release" nature of the nutrients present in composts (e.g., nitrogen) may be seen as a disadvantage in some situations as well.

The nitrogen content of composts is often of great interest to growers who want to know what nitrogen contribution they can expect from a given application of compost. Nitrogen transformations in active and finished composts and compost amended soils are complex, but they can be managed. For both economic and environmental reasons, minimizing nitrogen losses from composting and cropping systems is important. When excess water is added to a compost pile, either through irrigation or precipitation, the surplus water leaches through the system. This water can carry significant amounts of nitrogen as organic-N, NH_4 and NO_3, especially early in the composting process. Nitrogen losses from this process can be avoided by preventing the addition of excess water to the compost pile or by recycling leachate back into the pile. This will require some management effort, but it is certainly an achievable objective.

Controlling losses of gaseous forms of nitrogen is not as straightforward. An initial C/N ratio of 25:1 to 30:1 is usually regarded as optimum for rapid composting. However, significant amounts of gaseous nitrogen may be lost from compost piles with initial C/N ratios in this range; this is particularly true with composting materials which have high concentrations of ammonium and urea such as poultry manure. Gaseous nitrogen losses are primarily as NH_3 but also include NO_xs. Several management practices can be employed to reduce N volatilization from compost piles. Unfortunately, some of these practices may slow the composting process or result in anaerobic conditions in the pile. Increasing the initial C/N ratio of the compost blend (e.g., to 40:1-50:1) may help reduce N volatilization early in the composting process. As the C/N ratio drops during composting, N volatilization is less likely because much of the N has been assimilated by microbes and converted into organic molecules. Reducing the pH of the pile can help reduce NH_3 volatilization since high pH pushes the equilibrium between NH_3 and NH_4^+ toward NH_3. Similarly, materials such as phosphates and clays and with high sorptive capabilities may help reduce NH_3 volatilization. Reducing gas exchange (e.g., by less frequent pile turning) can also reduce losses of volatile N compounds; however, this practice reduces O_2 and CO_2 exchange as well.

Most well managed and well cured composts contain 1.5 - 2.0% N. Usually most of this N is organic-N and very little is in a mineral form. With typical application rates (e.g., 3 - 6 T/A) incorporation of compost generally does not have a marked immediate impact on the availability of mineral N in the soil. Because the C and N are balanced in the compost, net short term N release (or immobilization) is usually negligible. However, incorporated compost does decompose and N mineralization proceeds under most field conditions. Predicting rates of net N mineralization from composts is difficult. Such rates are influenced not only by the inherent properties of a given compost but also by factors such as soil type, previous field history, and the current crop and weather and management decisions. N mineralization rates from composts are generally slower than those for manures with similar C/N ratios. First year N mineralization rates may average 20 - 30%, but significantly lower and higher numbers have been reported. The N from a given application of compost will continue to mineralize over the period of several years. In most situations, the N contribution from compost applications will not be sufficient to supply all of a crop's N needs and other sources of N must be utilized in conjunction with composts. However, when calculating N budgets and developing N fertility strategies it is very important to estimate the N contribution of composts, including those applied in previous years.

Composts also contain many other macro- and micro-nutrients. In the absence of losses due to leaching, most mineral nutrients are conserved during composting. However, there is considerable variability in the nutrient content of various composts because of the variation that exists in the starting materials for composts. Typical concentrations of selected minerals present in manure based composts are presented in Table 2. The value of composts in improving soil fertility includes factors beyond their elemental nutrient content. The availability of some nutrients contained in compost can be superior to that of some other sources of these nutrients. For example, the availability of compost P is superior to that of rock phosphate and comparable to that of superphosphate. In addition to serving as a source of nutrients, composts may affect the availability of nutrients in the soil. Composts can increase the cation exchange capacity of soils, thus allowing increased availability of Ca, Mg and K. Composts can help neutralize and buffer soil pH as well as. This may increase the availability of many plant nutrients which become less available when soils become too acid or alkaline.

The addition of compost to a soil can have benefits beyond increasing the amount and availability of plant nutrients. Many arid region soils have low amounts of organic matter, especially when under continuous cultivation. Adding composts to these soils can have a significant effect on soil organic matter content. For example, the addition of 5T/A of compost to a surface soil containing 1% organic matter would increase the organic matter content of this soil to approximately 1.25%, or a 25% increase in total soil organic matter. Some of this organic matter will start to mineralize immediately. However, because composts contain a significant amount of complex, relatively stable organic matter, a significant amount of the organic matter would be expected to remain at the end of the season.

The addition of compost to the soil and its further decomposition can also stimulate soil microbial diversity and activity. The net effects of increasing soil organic matter and biological activity can be very beneficial. Soil physical properties such as soil structure and aggregate stability can be increased which may help improve soil porosity, water penetration and movement within the soil, and root growth. Suppression of soil borne diseases may also result. The diverse microbial communities which can exist in composts and compost-amended soils may include organisms which reduce pathogenic microbe populations and/or activity through a variety of mechanisms, including competition, parasitism and antibiosis. The level pathogen suppression of some composts is sufficiently high that they are used specifically for this purpose in container soils in the horticultural industry.

The above discussion outlines many of the potential benefits of using composts, as well as some of the variability that exists within all of the various materials that may be called "compost". Thus, for any farmer considering the use of composts, the issue of quality is critically important. There are many factors which can be considered in determining compost quality (see Table 3.), and the importance of these factors varies with the intended use of the compost. For example, with respect to at least some factors, the quality of a compost intended for field application several weeks prior to planting may not have to be as high as the quality of a compost that is intended for use in a container mix. The quality of a compost is determined primarily by two factors: the composition of the starting materials and the composting process. With the implementation of AB 939, the amount of materials entering landfills in California is decreasing dramatically. An increasing percentage of the organic portion of the state's waste stream, including green waste, sewage sludge, etc., is being diverted into composting operations. Many of these composting operations assume that agriculture will be a major consumer of their finished product. However, many growers are reluctant to use compost that originated from non-agricultural sources. In fact, the quality of the different composts that are, and probably will be, available is highly variable. Some commercially available composts are excellent materials, while others have significant quality problems.

Given the number and diversity of factors that contribute to compost quality, growers will need be thoughtful in evaluating the quality of a given compost. Information about the starting materials and composting process are very valuable in preliminary evaluation of composts and should be available to the customer at no cost. Many compost producers may also provide laboratory analysis data for plant nutrients, salts, and/or contaminants such as heavy metals and pathogens. When such information is not available from the producer, knowledge of the starting materials and composting process can give the customer at least an indication of potential problems that s/he may wish to have evaluated through laboratory analysis or by other means. While the ancient admonition, "Let the buyer beware," should be well heeded in the modern compost market, the interested customer should not be dissuaded from seeking out (or perhaps producing) high quality compost. There are many satisfied growers who have been using high quality purchased composts to improve their soils and crop performance in California for many years.

Table 1. Primary criteria for thermophilic composting.

Factor	Acceptable Range	Optimum Range
C:N ratio (@ start)	20:1-40:1	25:1-30:1
H_2O content	40-70%	50-60%
O_2 concentration	>5%	>10%
pH	5.5-9.0%	6.5-8.0%
Temperature (thermophilic stage)	110-150°F	130-140°F

Table 2. Typical nutrient concentrations for manure-based composts. (dry matter basis)

N:	1.0-2.0%	K:	2.0-3.0%
P:	0.3-1.0%	Na:	0.5-1.5%
Ca:	3.0-6.0%	Cl:	0.5-1.5%
Mg:	0.5-1.5%		

Table 3. Compost quality criteria.

<u>Chemical</u>	<u>Biological</u>
pH	Maturity/activity
Nutrients	Weed seeds
Salts	Animal pathogens
Metals	Plant pathogens
Organic compounds	Pathogen suppression
(pesticides, etc.)	Plant response (bioassay)
<u>Physical</u>	
Particle size	
Contaminants	

EVALUATION OF SURGE IRRIGATION IN THE SALINAS VALLEY

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INTRODUCTION:

Surge irrigation is a method of surface irrigation that uses intermittent flow of water into the furrows. The water is applied to a set of furrows for a period of time and then turned off for a time. This on/off flow is often accomplished by using a surge valve that alternates the continuous flow from the pump between two groups of furrows. While water is flowing in one group of furrows the water is off in the other group. This switching between groups of furrows is generally repeated from four to six times.

Studies have shown that the on/off cycle reduces the infiltration rate of the soil, which allows the water to advance across the field more rapidly. In some tests in the Salinas Valley, the surge technique used less than half the water to reach the end of the field as compared to conventional continuous flow. The reasons for this reduction in infiltration are not well understood but some possibilities are: 1) Surging causes air entrapment that slows water movement into the soil, 2) Surging consolidates the soil particles and seals the soil surface, 3) Infiltration rates are lower in a wet soil than in a dry soil.

The main advantage of surge irrigation is that the amount of water needed to advance the furrow stream to the end of the field is reduced. Any reduction of water used in the advance phase can usually be considered "saved." A more rapid advance will also result in a more uniform irrigation with less over-irrigation at the head end of the field.

Since surge irrigation also reduces the intake rate of the soil, smaller increments of water can be applied. This is important because often only small increments of water are required to replenish soil moisture in many vegetable crops. In all the fields where surge irrigation was tested, the lower amount of water applied by the surge irrigation was still sufficient to meet crop needs.

Although it does not work in all soil types, where it does work, it can be very effective in increasing irrigation efficiency and saving water.

PROCEDURES:

Comparisons were made between continuous and surge irrigation with grower cooperators on many different soil types throughout the Salinas Valley. All fields were irrigated with gated pipe. Eight adjacent furrows were used for the test. Four furrows, representing one pass of the tractor, were irrigated by the normal grower practice. The other four furrows were irrigated by the surge technique.

The surging was accomplished by opening and closing the gates manually. Four individual surge cycles were used in these tests. In the first cycle, the water was on until the furrows reached a distance approximately one quarter of the total field length. Then the gates were closed for a period of time equal to the time the water was on. The gates were then opened, and the second surge was run until the furrows reached the half way point. Again, the gates were closed for a period of time equal to the time the water was on. This procedure was repeated for the third and forth surge cycles, advancing the water three-quarters of the way down the field and to the end of the field.

Flumes were installed to measure the inflow in each of the eight test furrows. Flume readings were recorded every 20 minutes and at the beginning and end of each surge cycle in the surge furrows. Flume measurements were also taken if the flow changed for some reason such as the irrigator adjusting the gates.

The time and distance of the water advance was also recorded every 20 minutes. In the surge furrows, additional time and distance measurements were made when the water was turned off, when the water stopped advancing (water continues to advance in the furrows after the water is turned off due to surface storage) and when the next surge had traveled over the previously wetted area.

RESULTS:

The figures below show typical comparisons of the advance curves of surge and continuous flow. The surge advance curves tend to be in the form of stair steps with vertical lines representing the off-time (time passing with no increase in distance) and fairly horizontal lines representing the on-time. The horizontal nature of the on-time advance curve of surge irrigation shows that when the water is on it is advancing much more rapidly than the continuous flow curve.

Fig. 1 Cumulative time for the water to reach the end of the field.

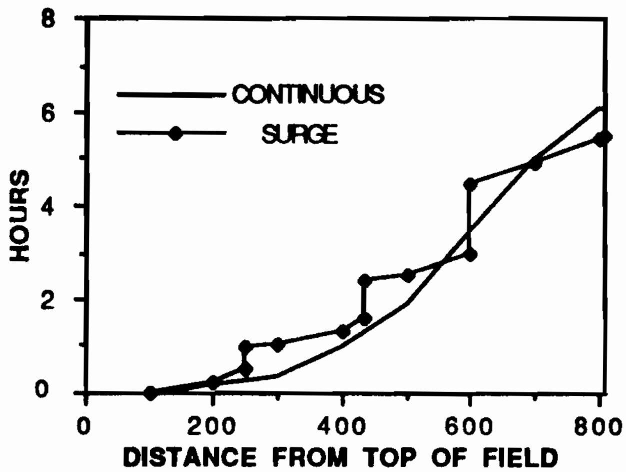

Fig. 2 Cumulative gallons applied to the furrow to complete the advance phase.

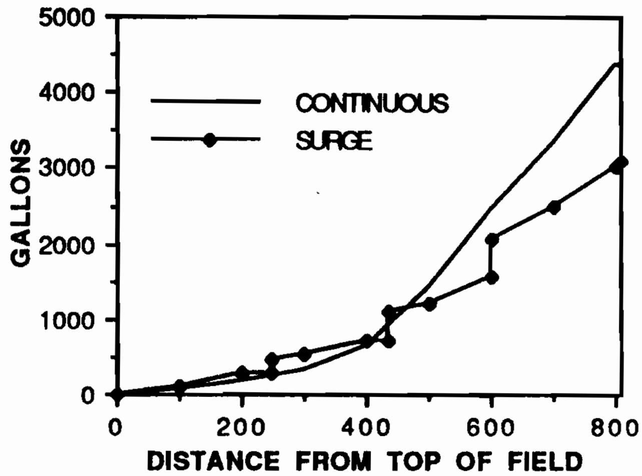

Table 1 on the following page shows the results from 21 surge tests performed in the Salinas Valley. Results were highly variable ranging from surge using more water than continuous flow to surge using only about one third as much water to complete the advance phase. There was no correlation between soil texture and the effectiveness of surge irrigation in these tests.

Currently there is no easy way to predict the effectiveness of surge irrigation at a particular site. More information is needed on the mechanism by which surge irrigation reduces the infiltration rate before a method of predicting its performance can be developed.

TABLE 1. RESULTS OF SURGE FLOW TESTS ON VARIOUS SOIL TEXTURES IN THE SALINAS VALLEY

Soil Texture	Furrow Length	Inches of Water Used to Complete the Advance Phase of the Irrigation. Continuous Flow	Surge Flow	Percent Saved by Surge Irrigation
Loamy Sand	750	2.34	.93	68%
Loamy Sand	640	.54	.53	2%
Sandy Loam	530	2.68	2.49	7%
Sandy Loam	1200	1.08	1.04	4%
Sandy Loam	1000	1.06	.69	35%
Sandy Loam	1030	2.36	2.33	1%
Loam	850	1.28	.91	29%
Loam	780	2.76	2.43	12%
Loam	800	.95	.96	-1%
Loam	810	3.49	2.19	37%
Loam	525	1.84	1.15	38%
Shaly Loam	590	1.60	.52	68%
Shaly Loam	590	.46	.33	28%
Sandy Clay Loam	870	6.33	2.89	54%
Sandy Clay Loam	1160	2.24	1.89	16%
Silt Loam	670	2.78	1.72	38%
Silt Loam	755	2.99	2.19	27%
Silty Clay Loam	600	4.97	3.15	37%
Silty Clay Loam	690	2.03	2.32	-14%
Clay Loam	590	1.63	1.52	7%
Clay	560	1.33	1.13	15%

ETHEPHON—A PLANT GROWTH REGULATOR—INCREASES THE PRODUCTION OF SERRA WHEAT

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Good cultural practices for Serra wheat that provide adequate fertilizer and moisture for maximum economical yields frequently result in this variety lodging. Lodging can severely reduce grain yields and quality.

The plant growth regulator Ethephon applied in the late boot stage (Feeks scale 9.5) significantly increased grain yields in 1990 and 1991. Wheat yields were high both years, ranging from 10,170 to 9,022 kg/ha in 1990, and 11,734 to 10,499 kg/ha in 1991. Ethephon, applied at the rate of 0.56 kg/ha a.i., increased wheat yields 1,148 kg/ha in 1990, and 804 kg/ha in 1991.

The Ethephon treatments increased kernel size. The increased kernel size accounted for approximately 95% of the higher yields in the treated plots in 1990.

Ethephon applications reduced the height of the wheat plants. The average height of the untreated wheat was 107 cm in 1990 and 113 cm in 1991 compared to the 0.56 kg/ha Ethephon-treated wheat measuring 100 cm (1990) and 103 cm (1991).

Lodging was reduced from 76.25% to 8.25% in the Ethephon-treated plots (0.56 kg/ha) in 1990. The untreated plots in 1991 averaged 82.5% lodging compared to 1.3% in the Ethephon-treated (0.56 kg/ha) plots.

The lodged wheat increased harvest time. In 1991, the harvest time was 34.5 seconds per plot in the Ethephon (0.56 kg/ha a.i.) plots compared to 67.8 seconds in the untreated plots.

In 1991, the additional topdressing of 45 kg/ha of nitrogen increased wheat yields from 11,302 kg/ha to 11,734 kg/ha when Ethephon was applied at 0.56 kg/ha.

The late application of nitrogen (45 kg/ha) showed a trend to increase the percent protein.

COTTON RESPONSES TO DEFICIT SUBSURFACE DRIP IRRIGATION

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Drip irrigation can be managed to minimize water and nutrient stresses and produce high dry matter accumulation rates. In order to conserve water, balance vegetative versus reproductive growth, and produce high lint yields, however, it may be desirable to restrict irrigation during part of the growing season. A three-year subsurface drip irrigation study was conducted to evaluate the response of three cotton varieties to irrigation ranging from moderate to mild deficit levels during specific parts of the growing season. Crop water requirements, a modified crop coefficient and growth responses were determined, and plant water, nutrient and gas exchange responses were identified. Peak lint yields were in the 2500 to 2700 kg ha range and did not increase significantly at evapotranspiration in excess of 700 mm.

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DRIP IRRIGATION UREA-N RATE EFFECTS ON pH, NITRATE AND CATION DISTRIBUTION

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Five rates of urea-N each at two water levels (0.6 & 1.0 ET) were applied to almonds (*Prunus dulcis* (Mil) D.A. Webb) planted in 1981 on a 3.65 X 5.47 m spacing (550 trees ha^{-1}) on Arbuckle gravelly loam (Fine-loamy, mixed, thermic Typic Haploxeralf). Trees were drip irrigated to basins (3 per tree) approx. 7 cm deep and 30 cm in dia. located 76 cm and 183 cm on either side of the trees. Cumulative N rates applied from 1982-92 were 1.3, 2.6, 5.2, 7.9 and 10.7 kg per tree respectively for the five treatments. They were applied monthly in 4 to 6 increments beginning in April. Soil samples were taken the fall of 1992 in 15 cm increments to a depth of 300 cms under the emitters and to lesser depths at 5-thirty cm increments from the emitter equidistant (75 cms) from the trunk. The two lower N rates at both water levels had lower NO_3-N levels (<10 mg kg^{-1}), generally lower NH_4-N levels and less change in pH than higher N rate trts. Intermediate and high N rates at the lower water level had greater accumulation of NH_4-N and NO_3-N (>100 mg kg^{-1}) than at the higher water level. More of the drip zone showed greater acidification (pH 3.4 to 5.0) at the higher water level at the two higher N rates.

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Comparison of Microbial Population Dynamics in Conventionally and Organically Managed Tomatoes

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Organic agricultural management systems are distinguished from conventional systems by their high carbon input, use of cover crops and manure rather than mineral fertilizers, and absence of pesticide use. The Sustainable Agriculture Farming System Project at U.C. Davis has completed the fifth year of a long-term study comparing organic, low input and conventional farming practices in tomatoes, corn, wheat, beans, and safflower. Microbial biomass and activity parameters were measured during the 1990, 1992, and, more intensively, the 1993 growing season in conventional and organic tomatoes. Microbial biomass carbon (MBC) varies seasonally, rising in the early spring, dropping in mid-summer, and slowly increasing over the fall and winter. During the transition period to organic between 1988-1992, MBC has become significantly higher in the organic and low-input than conventional systems. In 1993, substrate-induced respiration and arginine ammonification rates, microbial biomass N, potentially mineralizable N, and bacterial-feeding nematodes are significantly higher in the organic than conventional plots over most of the growing season. High levels of microbial activity and biomass in organic before incorporation are likely due to presence of cover crop, instead of bare fallow, over winter. Sharp declines in biomass and activity measures occur in the mid-growing season and may be due to high mineral fertilizer levels in conventional and to moisture stress in both systems. In 1993, nitrate and ammonium levels are consistently low with little fluctuation in organic, whereas high levels of mineral N are observed for approximately 45 days after side-dressing in conventional. The C:N ratio of total organic inputs to the organic tomatoes is substantially higher in 1993 than in previous years. Tomato yields, however, are not significantly different in organic and conventional. Data suggest tight coupling between mineralization and plant uptake of N in organic.

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ANALYSIS OF N UPTAKE BY CORN CROPS COMPARING N INPUTS FROM FERTILIZERS AND COVER CROPS

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A 5 year study (1987-1991) of an intensive corn-tomato rotation in Northern-Central California was undertaken to compare the effects of N inputs from mineral fertilizer and cover crop management systems. on soil nitrogen dynamics and crop response. Soil N input was managed by either various levels of ammonium sulfate application with a bare winter fallow, or winter grown leguminous, mixed and non-leguminous cover crops. Multiple regression analysis was performed to compare the sources of variance in N uptake between the two management systems. The significance of the inherent soil fertility covariate decreased in the cover crop system and increased in the mineral fertilizer system over the years. This study demonstrates that crop N uptake in relation to N inputs is comparable between the two management systems.

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EFFECT OF PLANTING DENSITY AND SALINITY STRESS ON WHEAT YIELD

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Field plot studies were conducted for two years at Brawley, California on semi-dwarf wheat *(Triticum aestivum* L.) cultivars, "Yecora Rojo" and "Anza" to determine the interactive efforts of salinity and increased plant population on seed yield components. Saline treatments were imposed by irrigating with water that contained NaCl and $CaCl_2$ (1:1 by wt). Electrical conductivities of the irrigation waters were 1.3, 5.0, 10.0, and 15.0 dS/m the first year and 1.3, 8.0, 16.0, and 24.0 dS/m the second year. Plant populations used both years were approximately 190, 275, and 550 plants/m^2. Increasing plant population reduced the number of tillers per plant and the weight of main stem and tiller spikes, but increased the total number of spikes harvested and total seed yield. Increasing levels of salinity tended to reduce seed yield and all yield components within each population, with the exception of main stem spikes. The reduction in seed yield caused by salinity was significantly less the higher the plant population.

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SALINITY EFFECTS ON LEAF APPEARANCE IN SPRING WHEAT

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Two hard, red spring wheat cultivars "Yecora Rojo" and "Anza" were grown in field lysimeters over two cropping years (1989 and 1990). The electrical conductivities of the irrigation waters were 0.9, 10.7, and 17.2 dS/m in 1989 and 0.8, 11.4, and 17.1 dS/m in 1990 to give control, medium, and high salinity treatments, respectively. Leaf number was regressed against thermal time to give leaf appearance rate (LAR). In both years the number of mainstream leaves as well as LAR of both cultivars were reduced by the medium salinity treatment. Increased salt stress had no further effect on these parameters. Salt stress accelerated time-to-maturity of Yecora Rojo and Anza by 3.5 and 5.1 phyllochrons, respectively. However, the durations of both pre-emergence and post-emergence stages of foliar development were insensitive to salinity. The phenological stages that are accelerated by salinity and that contribute most to reduction in time from planting to maturity appear to be those associated with growth and development of reproductive structures.

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VARIATION OF THRESHOLD VALUES OF ROOT ZONE SALINITY AND A DYNAMIC SALINITY STRESS INDEX FOR TWO SOY BEAN CULTIVARS

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A dynamic salinity stress index (SSI) is defined in terms of the integrated salt flux to the shoot relative to its growth rate. The index intrinsically responds to the parameters in the soil-plant-air continuum. A threshold value of this index has previously been shown to exist for tomato (*Lycopersicon esculentum* Mill) and is invariant to root zone temperature and atmospheric carbon dioxide. This experiment compares the plant response function of two soybean cultivars (*Glycine max* (L.) Merrill), Jackson, a Cl includer and Lee, a Cl excluder, using root zone salinity and SSI as indices of salt stress. Both cultivars exhibit similar responses to root zone salinity with Lee having a slightly higher salt tolerance. In contrast, the SSI based plant response functions show that both cultivars are very sensitive to Cl flux to the shoot with yield decline being initiated at very small values of SSI. Furthermore, the SSI based yield decline is greater for Lee than for Jackson, indicating that at the cellular level, Jackson is more salt tolerant than is Lee.

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NUTRIENT CYCLING IN CALIFORNIA OAK-WOODLAND GRASSLAND ECOSYSTEMS

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The influence of vegetation on watershed stream chemistry is revealed by nutrient cycling studies. We analyzed the cycling of the major cations and anions in an oak-woodland annual grassland ecosystem in the western Sierra foothills by characterizing the standing pools and annual fluxes. Precipitation, throughfall, stemflow, and soil solutions were analyzed to estimate the nutrient fluxes in this ecosystem. Estimates of seepage were calculated by water balance based on hourly soil moisture data from resistance blocks installed both under the oak trees and in the open grasslands. Nutrient uptake by vegetation was calculated by adding nutrient returned (litterfall, throughfall, stemflow) to the annual increment. Recycling of nutrients was calculated from seasonal analysis of nutrient concentrations in the leaves and nutrient concentration and mass of annual litterfall. Oak trees acquire most of their water and nutrients from Bt and Cr horizons (30cm-1m). Nutrients are more tightly cycled and retained in the system by oak trees than in the open grassland. Large nutrient fluxes were returned annually by oak trees to the surface soil through litterfall, leaf filtering, leaching, and stemflow. Grass acquires most of their nutrients in the A and AB horizons at 0-30 cm. More nutrients were leached below the rooting zone under grass than under the oak trees.

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STRUCTURAL STABILITY OF ARID-ZONE AS AFFECTED BY ELECTROLYTE CONCENTRATION AND SILT COMPOSITION

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Maintenance of soil structure is a major concern in the irrigation of soils. The flocculation-dispersion behavior of the clay fraction affects soil structural stability. Recent studies have indicated that even for samples with the same clay mineralogy, large differences in their stability exist. We used the dispersive behavior as a measure of stability of five soils having similar clay mineralogy and different textures, with silt content greater than 50%. We equilibrated the soils with different electrolyte concentrations and sodium adsorption ratios. The results showed substantial differences in their structural stability. Particular attention was paid to the silt fraction to explain these differences.

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MICA TRANSFORMATIONS IN 41-YEAR-OLD SOILS DEVELOPED UNDER OAK AND PINE

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Vegetation effects on 2:1 phyllosilicate mineral transformations were investigated in 41-year-old lysimeter soils of the San Dimas Experimental Forest. Original lysimeter fill material was a diorite-derived sandy loam with 10% clay. Soil profiles under oak (*Quercus dumosa*) and pine (*Pinus coulteri*), monocultures since 1946 and sampled in mid-1987, were analyzed using x-ray diffraction, and compared to the original archived fill material corresponding to the sampling depths. Integrated peak area ratios of Mg-saturated, glycerol-solvated clay indicated a dramatically higher proportion of mica (1.0 nm) relative to vermiculite (1.4 nm) in the A horizon under oak, compared with corresponding archived fill material. No change from original fill material was observed in the 1987 A horizon under pine, nor in subsoil samples under either vegetation type. Differences between monocultures may be due to more efficient biocycling under oak, resulting in greater surface soil concentrations of K^+ and NH_4^+. These cations may be fixed in vermiculite interlayers, causing collapse to the 1.0 nm d-spacing.

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MOISTURE DEPLETION IN WEATHERED GRANITIC ROCK UNDER CHAPARRAL

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Chaparral in California is frequently underlain by soils only a few centimeters thick. Roots penetrate deep into weathered rock, both along joint sets and within the matrix of softer rock. We monitored water depletion from the weathered rock by chaparral using neutron activation. Monitoring was done in adjacent cleared and unaltered plots form the end of the rainy season (March) through the following summer and fall dry season. Water depletion was measured in five access holes, ranging from 1.9-3.9 m in depth, at each plot. Preliminary data (June) show significant water depletion to a depth of 2 m in the unaltered chaparral plot, but only to a depth of 0.25 m in the cleared plot.

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RESPIRABLE SILICA FROM AGRICULTURAL MANAGEMENT SYSTEMS IN CALIFORNIA'S CENTRAL VALLEY

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The health effects and air quality degradation due to emission of dust from agricultural management practices are of growing concern to environmental regulatory agencies and to the public at large. We measured total an respirable (<3.5 μm diam.) dust produced by a variety of rice, grape, and citrus production management operations. Quartz concentrations in the dust fractions were measured by x-ray diffraction and related to soil particle-size distribution and crop management. From rice operations, total quartz concentration in the dust ranged from 0.04 to 0.90 mg m^{-3} air. Respirable quartz ranged from 0.02 to 0.08 mg m^{-3} air, concentrations that are below the OSHA permissible exposure level of 0.1 mg m^{-3} air. Initial data from grape and citrus operations show that respirable quartz concentrations in dust from citrus management operations ranged up to about 0.18 mg m^{-3} air, about twice the OSHA limit, whereas respirable quartz concentrations in dust from grape operations were < 0.07 mg m^{-3} air and do not exceed OSHA limits.

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$Cd+2$ ACTIVITIES IN SLUDGE-AMENDED SOILS

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The bioavailability of trace metals in soils is dependent on their speciation in solution, and in particular on the activity of the free metal. There is no standard method to determine free metal activities in soils. We compared free Cd^{+2} activities determined by four different methods in synthetic and soil solutions. The synthetic solutions ranged from a simple noncomplexing inorganic matrix to a complex matrix resembling a soil solution. Cd^{+2} activities determined by ion selective electrode, an addition method and the computer program, GEOCHEM, closely agreed. Cd^{+2} activities determined by the chelation method did not agree with other methods.

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HIGH RESOLUTION TDR MEASUREMENTS AND ANALYSIS

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When using the time domain reflectometry (TDR) technique in laboratory experiments, e.g., packed soils columns, it will often be of a great importance to use very small TDR-probes, have a small distance between the probes, and measure close to the soil surface. In laboratory experiments on packed soils we have examined the importance of relations between probe diameter, probe lengths, distance between probes, and distance from the probes to the soil surface for correct determination of volumetric water content. The experiments were conducted on two different soils (coarse sand and fine sandy loam) over a wide range of water contents, with three different probe diameters (1,2,3 mm), two probe lengths (5-15 mm) and at distances to the soil surface varying from 1-50 mm. The theory by Knight, 1992 (Water Resources Research, 28:2345-2352) has been applied as an attempt to theoretically explain the results.

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DIFFUSION, ADSORPTION, AND BIODEGRADATION OF VOLATILE ORGANIC COMPOUNDS

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Many Volatile Organic Compounds (VOC's) co-exist at sites of underground contamination. Under unsaturated moisture conditions, molecular diffusion in the gaseous phase becomes the main transport mechanism of these compounds. At low concentrations, this mechanism can be described by Fick's first law. Where some physical and chemical properties may not be greatly changed under these conditions, the biodegradation process is directly impacted. Batch experiments show that co-metabolic transformations of some VOC's occur in the presence of a primary substrate. However, such transformation curves may not be applicable under transient conditions due to changing substrate levels in the soil. This study examines the evolution of the biodegradation curve under aerobic conditions during transient gaseous diffusion. Biodegradation models both allowing and not allowing for microbial growth are tested for best fit of the degradation curves of both compounds involved in the co-metabolic degradation process.

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PROGRESS IN BREEDING FOR RESISTANCE TO LYGUS IN BLACKEYE COWPEAS

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Host plant responses among legume species and genotypes subjected to feeding by populations of the tarnished plant bug *Lygus hesperus* are the result of interactions between numerous environmental and genotypic factors. Breeding for enhanced levels of lygus resistance in cultivars of blackeye cowpea (*Vigna ungiculata*) is designed to be a part of integrated lygus management that includes crop rotation, the use of trap crop species, and manipulation of planting date based on monitoring of insect populations. In controlled greenhouse and field studies, selected blackeye genotypes were observed for difference in bud, flower, pod, and seed responses to contrasting levels of lygus pressure for a prescribed length of time. Grain yield and total plant biomass varied significantly among genotypes, and indices of genotypic recovery potential were recorded. Management of hybrid progenies in lygus screening and selection nurseries has been adjusted according to results from the controlled studies and to reflect strategies to combine selective use of insecticides with genotypes that demonstrate recovery potential following lygus attack.

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WINTER COLOR RETENTION BY ZOYSIAGRASS CULTIVARS IN CALIFORNIA

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Warm season turfgrasses are well adapted, low input species for California. They are not used extensively, however, because of winter dormancy, which is the result of chlorophyll degradation caused by the interaction of low temperature and high light intensity. Twenty-eight zoysiagrass cultivars and selections were established at Riverside and Irvine, California, in 1991. It was found that considerable variability existed among the grasses in terms of color retention - color loss and that variability was consistent by grass and location. Those grasses that strongly held color at both locations included the experimental lines DALZ 8502, UCR Z88-8 and UCR Z88-14. Grasses characterized by early onset of dormancy included CD 259-13, GT 2047, JZ-1, Korean Common, TC 5018 and TGS-B10.

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ZINC NUTRITION OF AVOCADO

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Zinc and other trace metal deficiencies are common in many southern California avocado orchards and are suspected to be an important limiting factor in fruit production and tree health. Several methods have been developed to correct this problem including foliar applications of zinc sulfate and zinc chelates, trunk injections, or soil applications of zinc fertilizers to increase zinc availability. However, currently there is no consensus as to which application techniques are the most effective and which materials are best used with the various application techniques. The objective of this research was to compare currently recommended treatments to determine which methods are actually the most effective for correction of zinc deficiency on a calcareous soil.

Eight different zinc treatments were established using a completely randomized design for the soil treatments and trunk injections, and a block design for the foliar spray applications. Leaf samples were analyzed for zinc, iron, and manganese in January, May, and August 1993. Ten leaf samples were collected from individual trees in each treatment, washed, and acid digested for analysis by flame atomic absorption spectroscopy.

The experiment revealed clear differences among the zinc fertilizer materials and application methods that were particularly evident at the last leaf sampling date on August 31, 1993. All of the treatments, with the exception of trunk injection, provided some improvement in the zinc content of the foliage. However, the most effective treatments were foliar applications, followed by soil banding of zinc sulfate. The least effective treatments were trunk injection and quarterly applications of chelated zinc or zinc sulfate to the soil. When applied as a foliar spray, all of the zinc materials tested were effective for increasing foliar zinc content in comparison to the control trees. However, with respect to overall ranking, the chelated zinc material, Zintrac-8, gave the best response, followed by zinc sulfate, and lastly by Zinc Metallosate.

Given the low cost of zinc sulfate, this material may be the most cost effective for foliar applications. However, further tests are needed to determine how these materials compare in penetrating the leaf cuticle. Assays are also needed to determine the efficacy of different foliar applied materials and surfactants and their ability to improve internal zinc availability as opposed to coating the leaves with unavailable zinc precipitates.

NITRATE LEACHING IN A TURFGRASS ENVIRONMENT

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Concerns over nitrate contamination of drinking water have led to a re-evaluation of nitrogen fertilizer management practices. This study examined the effects of fertilizer type (soluble and slow release), irrigation amount (100% and 130% of crop requirement), and soil type on the leaching of nitrate through turfgrass maintained under golf course conditions. Creeping bentgrass (*Agrostis palustris* var. Penncross) sod was used for green plots constructed on a 18-inch sand base. Fairway plots were constructed on two soil types, a sandy loam and a loamy sand, using a hybrid bermudagrass (*Cyndon dactylon* by *Cyndon transvaalensis* var. Tifway II) sod. Leachate and soil-water samples were collected weekly and analyzed for nitrate-nitrogen. Results to date indicate that approximately 0.5% of the applied nitrogen was leached as nitrate. No significant differences in mass of nitrate leached has been found for irrigation amount, fertilizer type, or soil type.

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