UNIFIED FEDERAL POLICY FOR ENSURING A WATERSHED APPROACH TO FEDERAL LAND AND RESOURCE MANAGEMENT

CLEAN WATER ACTION PLAN

Comments of Bud Hoekstra

ROUND RIVER

The author of *A Sand County Almanac*, himself a forester and a US Forest Service forest supervisor, dropped the term *watershed* for the more descriptive term *round river*, because he preferred a biogeochemical concept to the mere geography of location. Why is that important? Because water is a mineral, and that mineral cycles through the environment, first as a falling drop, then as run-off from a watershed, after moving as run-off, the mineral resorts to transevaporating, recharging, vaporizing, clouding and raining. The same drop, theoretically, falls on the same watershed time after time, and repeats the water cycle over and over again. Breaking up the cycle into *watershed's* is like breaking the sky into constellations, done so purely as matter of convenience and not for much else. On the other hand, Uncle Sam must start some place, and *watershed* is a good unit to start with, because Uncle Sam controls the watersheds on federal land.

In California, nature stores the drinking water for a vast majority of the citizens in snow packs of the mountains. These frozen watersheds melt during the year and distribute their mineral wealth to thirsty agriculture and economic centers of the valleys. Drinking water is in short supply, and would be nonexistent in some communities, if no snow fell. If the water cycle failed early on, if the winter precip didn't happen, California would go dry, communities would fold and people would vanish. Unlike gold which is affixed in the California earth in defined amounts, water is delivered to the upper mountains as an ecosystem service, as a biogeochemical cycle of Mother Earth. The cycle is perishable, and it would behoove Californians to monitor the workings of the round river which provides for the bounty of its fields and the amenities of its cities. Without water, California is nothing.

THE SKY IS FALLING

In our very rudimentary understanding of nature, the sky falls. The sky falls as wet rain, frozen snow, hail and other forms of water which we know as precipitation. Fog-fall nourishes the redwoods of the coast, and without this form of precipitation, California would lack its prized Big Trees. The language we use to describe this step in the round river is the words "*it rains.*" *IT*, we are taught in the very first years of our schooling, is a pronoun and pronouns have antecedents, pronouns take the place of a noun. *It rains.* What does the "*it*" in this phrase refer to? Native American languages, like Kalispel, a Salish lannguage, structure *tree* the same way. They say, "*it trees.*" Sanskrit readers always used the notorious phrase, "God rains," to describe the infrequent seasonal precipitation. We say, "*IT RAINS*," as if it had some meaning to us, but does it. "*It*" is pretty anonymous, and we don't know from our language experience whether the sky rains, the rain rains, the clouds rain or the precipitation rains. We talk of the rain as if it were a static object, a thing in the

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sky, like a glass plate or a plot of land. But it's hardly that. Rain is dynamic, it moves, it transmutes, it revives. Our most mercurial mineral, water cries from the sky, rolls down the cheeks of the earth and saturates its bowels, eventually to come back to the surface again in lakes and streams and oceans where the sun evaporates the moisture into the sky where it returns again as the tears we call rain, the life-giving tears that give all earth its green skin.

The Earth in its fullness has been called the green-blue planet from space, and the colors of our flagship planet actually identify its primary cycle, the round river, embodied in its oceans as blue and on its land as green.

Nature runs the round river within varying norms of volume and purity. Since time immemorial, lightning during rains has mineralized the component of air called nitrogen and has made it into a powder called nitrates. Nitrates are very important to our industrialized world: they are used in fertilizers and explosives, not to mention a hundred other products and commodities. Plants use the nitrogen to build proteins, which cows must eat and transform into milk, among products. We eat cheese, we dine on beefsteak, we munch corn of the cob; when we do, we eat the combined work of the round river and the nitrogen cycle, one depends on the other.

The biosphere - that's the blue-green planet and its mineral cycles - is run a little differently than we run our civilized society, sometimes dubbed the "noosphere" by biologists - that's /knew-oh-sphere/ from a Greek world meaning *mind*, because it is "nature" shaped by the tinkering of mankind. We make nitrogen, and we dump that nitrogen on our crop fields to make plants grow and achieve higher yields. The winds that play a role in the round river and pass clouds of water to and fro o'er the face of the earth pick up the aerosols of nitrogen that the farmers spray and erode the freshly furrowed soil by sweeping up its laden dust, giving nitrogen a ride in the sky. This unlikely hitchhiker adds to nature's store already in the air, sometimes doubling the amount already provided as an ecosystem service. Along with rain comes nitrogen, falling from the sky in amounts to which the watershed is not used to. The winds, so to speak, have become toxic with their added burdens of nitrogen, and the nitrogen falls on the thirsty soil.

The same winds carry a toxic burden of pesticides wherever they blow. Scientists, in coring the Arctic's ice cap, found a trace dusting of toxaphene, a pesticide used on cotton, in the layers of ice formed after 1940. Scientists who drilled on the island of Isle Royal, in the wilderness lake known as Lake Siskiwit, found other pollutants characteristic of industry - not to mention the salting of toxaphene from the air. Cotton, to my knowledge, has never been grown in the Arctic, nor has Isle Royal, a lake within a Great Lake, ever seen a harvester. But the effects of human activity, more precisely the artifacts of human agriculture, nonetheless salt the earth in unison with the water cycle.

We've known for a long time that rivers are polluted, that the Cuyahoga River near Cleveland caught fire and burnt like oil, such was the pollution. We only have glimpses of the round river and its burden of pollution. But round rivers are important, and it will pay many, many future dividends to know just how polluted they are. The way to start is to monitor the watersheds, to see what unlikely components of sky fall to the land in tainted tears.

In the pristine beauty of every watershed in the world are the products of belching smoke stacks and spewing tailpipes. We don't know how dangerous it all is, we don't know in what amounts these chemicals accrue. We hardly know what burdens of intoxicants are borne on the air each year and fall as rain upon the land, spilling into streams and lakes, dripping on trees and plants, like an invisible gas. The Round River fumigates the world with industrial wastes.

Less than a nanogram per meter square per rain... Nitrogen is essential to plant growth, and with no introduction to botany, one might be compelled to ask, "Does extra fertilizer matter?" Yes, it does. Nitrogen builds up and accummulates in some plants to make them toxic. Common beet tops, a fodder fed to livestock, can be poisonous on occasion from the accummulation of nitrates in the leaves. Early in the history of the herbicide 2,4-D, beet-growers sprayed the weeds growing between their planted rows with this chemical. The weeds died. The beets, which weren't sprayed directly, were affected. The trace 2,4-D caused them to accummulate nitrogen in their leaves, which, having been fed to livestock as feed, killed them - the cows. Common weeds like goosefoot and lamb's quarters also accummulate nitrogen, and several hundred plants, including crop plants, can accummulate nitrogen under the right conditions. Nature has always seen to it that the sky doesn't over-load the ground with toxic levels of nitrogen, but humans, unawares, may be fulfilling this prophesy.

Nitrogen in lesser amounts, in nonfatal accummulations, does more than just make proteins, the sustenance of life that no living thing can do without. In the veterinary literatures, nitrates in higher-than-normal doses lead to foaling disorders in horses, all from the accummulation of nitrates in plants. In Arizona and New Mexico, where aquifers - the underground lakes where rain collects - are contaminated, signs on camppground kiosks warn, "Infants under six months and adults with heart conditions should not drink from this water." Nitrogen is the basis for the angina treament known as nitroglycerine.

SCIENCE has documented unusual occurrences with nitrogen. Called nitrogen deposition, because the deposition can be dry, like a dust, or wet, like a rain, if rain cleans the sky of its nitrogen burden, the nitrogen cycle is out of whack. Far more nitrogen falls today than ever fell in nature before industrial times. The added salt of nitrogen does many things to vegetation. Nitrogen can make plants tastier for cows, and cows have been known to die from eating nitro - the explosives left in unblasted trees meant for clearing. Nitrogen can change the species of plants that grow upon the ground, giving weeds a growth spurt to out-compete the others. Generally, N-fall means that weeds get a boast and native species decline. Biodiversity loses in this scenario of upset. Even ranchers are affected: the BLM and Forest Service measure overgrazing by forulas that combine biodiversity with stubble height. Cows like their "ice cream" plants, and spurn their "cod liver oil." If they overgraze, the ice-cream plants disappear, and the cod liver oil species thrive. Nitrogen deposition can make those changes happen with or without cows.

In California, Yosemite National Park and the surrounding wilderness watersheds send Fresno county its water. Fresno County is the Iceberg Lettuce capitol of the world, they grow more lettuce there than any place else. The waters in Fresno, the well waters that is, the deep aquifers which the wells descend into, are tainted with nitrates and pesticides. Although the wells are cleaner now than they have been, the contamination remains, and that contamination is pumped into buildings and homes, which, every time a faucet is turned on, everytime a dishwasher runs, flood the indoor air with VOC's, airborne nitrates and pesticides.

The contamination starts in Fresno, where farmers spray their fields of lettuce with fertilizers which contain nitrogen. The nitrogen sinks into the soil, or drifts into streams, or, aerosol-like, spreads across the air, lifted by winds into the sky, where it travels into the mountains where rains wash it out or where it falls as a dry dust on the land. Rain washes the sky and the land carrying a load of dust from the snowmelt to the rivers that irrigate Fresno and recharge its aquifers. Eventually, the nitrogen works its way into the aquifer where wells withdraw it into the house. Cisterns which collect the flow from roofs of homes in the valley are laced with nitrogen and pesticides which taint the water. People drink the tainted water, people shower with it, and the showerhead mists the house and taints the indoor air. So the water cycle which starts on federal land, the round river, runs through our houses and our bodies, and if this river is polluted, it will pollute our homes.

Clean water is our most important forest product. Timber is money, but pure water is priceless. Water quinches our thirst, irrigates our food, raises our livestock and cools our cars. Water is the liquid substance of milk, the broth of soup, the beverage of beer, the agent to fight fires, the ingredient of blood, the puddle on the street, the medium in which fish live. All these aspects are part and parcel of the round river. The round river is *"round"* because it moves around, it is around - all-around, all-encompassing, comprehensive and we depend on it. Yet, the round river is in peril from the dangers of sub-nanograms of pollutants.

WATERSHED MECHANICS

The Round River wets the world. It rains on fields, it fills streams, it gives life to a thirsty world. Water makes up everything, 45% of earth's rock, 70% of our bodies, 99% of our oceans. The metal hydrates, the silicon crystals which contain water, lie outside the water cycle, external to the round river.

This water does not cycle, this water does not move. Water in the round river moves, it moves because of the sun, the engine of weather on the earth, and gravity - mineral water flows downhill - and plants and animals, which exhale water. Water is a product of sugar combustion in our bodies, we breathe. Forests breathe, or transevaporate, emptying the soil of its content of water sucked up by the roots of the plant. The moving water moves hard-to-move minerals like nitrogen, phosphorus, potassium, magnesium, sulfur and iron. We eat plants which supply us with these minerals in our diet. Water in our gut moves these minerals around to feed our individual cells.

We get our water from the kitchen faucet - or from the milk glass - and the faucet gets its water from the well - or the cow. The well gets its water from the aquifer which gets its water from the stream which gets its water from the mountain, the snow pack or the rainfall. Every step completes a circle, the round river is round.

In year 1999, the last year of the millennium past, the US was stricken with a drought of unusual proportions. Farmers east of the Mississippi suffered worse, and crops, like soy beans, went bad with small yields. Organic soils on the large Rodale farm in Emmaus, Pennsylvanis, weathered the 100-year drought well, because the soil, alive with microbes and tiny life-forms, held water longer than did the conventional soils of farms. Water retention is an *ecosystem service* performed by the plants and animals of the soil.

In the West, a major player in the cycle of the Round River is the gopher. The gopher buries its head and digs, tunnels through the otherwise hard pack of earth to create a maze of burrows which become water traps in the winter. Like snowfall, gopher holes trap and retain moisture, keeping the subsoil wetter longer for a longer growing season and a greater yield of biomass. Gophers aid in the storage of water and in water's infiltration into the soil. Infiltration cleans the water and recharges the aquifers from which urban centers drink. At present, nobody has calculated the capacity of the gopher's network of mini-aquifers in the subsoil, nor has any value been found for the ecosystem service of water retention which it performs. Yet, daily, gophers store water. Gophers burrow in soil and the Round River increases in storage capacity. As populations centers grow and depend on the work of the gophers, on the ecosystem service of water recharge and retention, it behooves all who drink to consider this wheel of the Round River - whether it still turns all right.

Just think of what it costs to make water from scratch, to clean it and purify it all, to squeeze it from rocks or to make a technology that desalts the oceans. The Round River already does all this for us. It desalts the oceans for free. It irrigates the land. It purifies and recharges our aquifers. All these ecosystem services are performed on the watersheds of America.

CONCLUSION

Trees have been called the "lungs of the earth" because they exhale water and oxygen. We drink water and inhale oxygen, which we can't live without. These ecosystem services are essential to our well-being, just as water, access to it, underpins the economy of California. No water, no life is nature's fundamental rule.

Our supplier, whether we pay EBMUD, SDUD or MPUD, is the earth. Clean water is a forest product, an ecosystem service, and while we know now that our ecosystems are in decay, it is time to look at what happens to water, to the round river and its services.

Given that we eat because of the round river, given that we drink from its ever-present flows, we need to manage the watersheds and monitor them, to check for function and performance, to ensure that ecosystem servives continue to be provided.

We need to monitor watersheds for unlikely pollutants, for nitrogen, mercury, 2,4-D. We need to know what trace contaminants build up in ice, fall in snow and wash out in rivers. We need to know what laden winds bring in, what effects these have, on water fleas, frogs, birds and trees.

Manion's *TREE DISEASE CONCEPTS* points out that trees do not die of disease alone, but die of a combination of factors which are dubbed stress. The precipitating factor might be aphids. But the predisposing factor might be nitrogen, which, in the environment, causes aphids to over-breed and multiply. An abundence of aphids can spread needle wilt, a disease of pine trees, which kills off our forest trees, like the Ponderosa pine which we use for lumber.

We need to understand the vulnerability of watersheds to degradation, and how we can cope with broad-band pollution in the highlands.

Every dollar that exchanges hands in California, the entire economy which is the fifth largest in the world, rivalling that of France, depends on the function and the service of the round river.

I applaud the federal government for taking steps to protect the round river, for making watershed management a must for the future.

We need to monitor these watersheds for the gasoline hydrocarbons, for nitrogen-loading, for acid rain.

Acid rain, it is known, dissolves the galvanized metal coating of pipes, which is mostly zinc and trace cadmium. Zinc is not toxic is dissolved amounts, but trace cadmium is, causing high blood pressure and kidney malfunction. Nitrates, which spoil every round river in the United States, are linked to diabetes. Phthalate esters, the plastizers in milk jug plastic, harms fish when it gets

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into the round river. Even hormone-mimics, which include pesticides, can disturb insect life and cause sea turtles to spawn all female offspring. The endangered red slider turtle may be in jeopardy because the trace PCB's, a hormone mimic, feminizes the egg cells.

Even the flush toilet, an invention of last century, has impacted the round river by spreading cholera. Cholera is toxic to humans because of the vibrio DNA - vibrio being a virus. Without that viral DNA, cholera is benign and harmless. Thinking ahead ten years, to a time of designer diseases, terrorists may be able to make a cholera with another toxin besides vibrio's and release it into the US watersheds.

Monitoring of watersheds is exigent. The plan should extend to all watersheds, not just federal. We need this program very much. It is perhaps the greatest thing that Uncle Sam has done since he created the national forests. I applaud the Clean Water Action Plan, I celebrate it. No other action by the federal government compares with it in the last century and a half, except perhaps the creation of the national forests. This is a monumental doing, a public good so great that I don't have words to describe it. The Unified Federal Policy for Ensuring a Watershed Approach to Federal Land and Resource Management is the greatest thing that America has going for the future. It is wonderful, it is exciting, it is monumental.

I read the account of the plan in the federal register, I read it through twice, and I can only say, having perused it well, that this plan is our children's prayer, the unuttered prayer in the mouths of our future generations. 100 years from today, history will record this policy for it is: a scientific window on watersheds...and our stewardship duty to the round river.

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Tallying Nitrogen's Increasing Impact

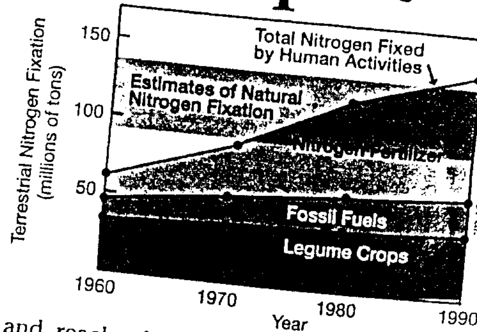
For most of agricultural history, nitrogen has been a precious commodity. Only specialized bacteria and lightning could convert atmospheric nitrogen into biologically usable forms. Today, however, fertilizers and fossil fuels have made nitrogen so freely available that it has become too much of a good thing.

In a review of nitrogen's effects across the environmental spectrum, a team of ecologists headed by Peter M. Vitousek of Stanford University has concluded in no uncertain terms that human activities have dramatically increased the flow of nitrogen into the biological world—doubling the natural rate at which it is made available on land—with "serious and long-term" consequences.

"We are now the dominant force in the nitrogen cycle," says ecologist G. David Tilman of the University of Minnesota in St. Paul, one of the report's eight authors. "Humans are controlling more nitrogen than all natural processes."

The Ecological Society of America is releasing a version of the report this week at the American Association for the Advancement of Science meeting in Seattle. The full report is slated to appear in the August ECOLOGICAL APPLICATIONS.

Although none of the data or processes summarized in the report is new, a synthesis was needed, says John M. Blair. "When people think of global change, they usually think of climate change and increasing carbon dioxide," says Blair, a soil ecologist at Kansas State University in Manhattan. But the growth and reach of human population has a global impact in other ways. "The nitrogen cycle is a terrific example of that."



The ecologists trace most of the new nitrogen in the system to three human activities. The use of commercial fertilizer is the biggest source, and it is increasing sharply, especially in developing countries. Of all the manufactured fertilizer used through 1990, half was applied to crops in the 1980s.

Increased global cultivation of legumes and other crops that harbor nitrogen-fixing bacteria also adds to the influx. The burning of fossil fuels provides the third major source of newly available nitrogen compounds. These activities funnel about 140 million metric tons of nitrogen into the environment each year, the ecologists estimate—an amount roughly equivalent to 10 million semi trucks of dry nitrogen fertilizer, says Tilman.

The clearing of wildlands liberates perhaps another 70 million metric tons of nitrogen that had been stored in biomass.

The nitrogen glut is evident throughout the biogeochemical cycle, according to the report. Nitrous oxide, a potent greenhouse gas (SN: 9/18/93, p. 180), is accumulating in the atmosphere and can eat away at the stratospheric ozone layer. Other nitrogen compounds contribute to smog and acid deposition. They alter the pH and nutrient balance of soils and waters, triggering a cascade of effects (SN: 2/11/95, p. 90; 7/22/89, p. 56).

Researchers now think that the excess nitrogen is diminishing biological diversity in some areas. European heathlands, long adapted to nitrogen-poor conditions, are giving way to Eurasian grasses under the fertilizing effects of nitrogen. Such changes in species composition (SN: 12/7/96, p. 356) may be the newest and most surprising of nitrogen's consequences, says Vitousek.

The trends are likely to continue, in step with the growing, urbanizing world population, the ecologists say. They see a need for more efficient fertilizer use and greater control of nitrogen emissions.

— *C. Mlot*

Car phones jack up risk of collisions

Driving while phoning may soon become as notorious a traffic offense as driving while intoxicated. Both practices at least quadruple a driver's risk of having a collision, a new study shows.

Donald A. Redelmeier and Robert J. Tibshirani of the University of Toronto have produced what may be the first large-scale evidence of car phone risk. They studied 699 Canadian drivers with telephones, all of whom were "involved in motor vehicle collisions resulting in substantial property damage but no personal injury."

The researchers drew their data from the drivers' cellular telephone records, police accident reports, and interviews with the drivers themselves. They then analyzed the drivers' telephone use on the day of their vehicular crack-ups and on the day before the collision.

Redelmeier and Tibshirani chose this method because it would enable them to "identify an increase in risk if there were more telephone calls immediately before the collision than would be expected solely as a result of chance."

The investigators found that each driver used the car phone an average of nine times on days in which collisions occurred. Twenty-four percent of the drivers had begun a call within 10 minutes of the collision. By comparing the same drivers' calling patterns on the previous day, the researchers calculated that phone use increased the likelihood of a collision 4.3 times.

The duo decided against analyzing collisions that involved serious injury, because they did not want personal injury lawyers to seize on the study as potential evidence in lawsuits. In court, the researchers might have to violate their vow of privacy to the people who volunteered for the research, Redelmeier says.

The study, published in the Feb. 13 NEW ENGLAND JOURNAL OF MEDICINE, provides "the first direct evidence" that cellular phones contribute to roadway collisions, Malcolm Maclure of the Harvard School of Public Health and Murray A. Mittleman of Beth Israel Deaconess Medical Center, both in Boston, write in an accompanying editorial.

The study does not suggest that people who were using cellular phones caused collisions, Redelmeier emphasized. Many of the drivers couldn't avoid cars that veered into them—even when using phones that allowed them to keep two hands on the steering wheel.

"I thought that the most striking observation was that hands-free cellular telephones offered no large safety advantage, suggesting that the major factor in a motor vehicle collision was not limited manual dexterity, but the driver's limited attention," Redelmeier says. Nearly 40 percent of the drivers used their phones to call for aid after the collision, he added. Half a million Canadians use cell phones to report emergencies each year.

Maclure and Mittleman found that the risk of a collision doubles within 5 minutes of starting a phone call. They calculate that if 1 driver in 10 has a car phone by the year 2000, driving while phoning could cost the United States alone up to $4 billion per year.

— *S. Sternberg*

New Scientist 29 April 1989

Laying the ground rules for nitrate

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Fertilisers applied to growing crops are not the major cause of nitrate pollution. The way we farm is. Has the current debate paid enough attention to what actually happens in the soil?

Tom Addiscott and David Powlson

"WITH environmental issues one needs a soft heart and a hard head." Few people would challenge this opinion, expressed recently by Virginia Bottomley, junior minister at Britain's Department of the Environment. Her department has published a paper entitled *The Nitrate Issue.** This "study of the economic and other consequences of various local options for limiting nitrate concentrations in drinking water" could form the backbone of government-enforced measures for controlling nitrate in water supplies. The options include "water options" such as blending water from various sources and removing of nitrate by chemical or biological means. There are also "agricultural options", restricting the way farmers use land and apply nitrogen fertilisers.

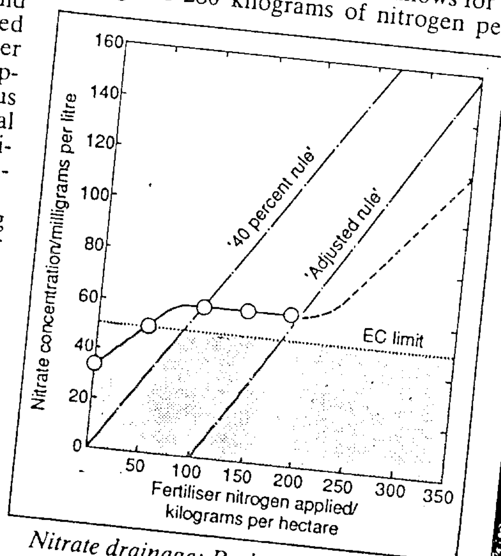
Pressure to control nitrate in drinking water comes mainly from the EEC rather than from medical research. But although it is prudent to minimise the concentration, this must be on a scientific basis. In some aquifers, control measures may need decades to become effective, so they must be right first time.

They also need to be right because of their impact on the lives of the farming community and on food prices. These measures must, in particular, take proper account of the complex web of physical, chemical and biological processes that contribute to the leakage of nitrate from soil. The "agricultural options" set out in the paper from the Department of the Environment (DoE) do not do so, and appear to be based on a misunderstanding of the problem.

The Nitrate Issue evaluates the agricultural options in a series of "desk studies" that use a computer model developed by the Water Research Centre (WRC). This is a good model, but as with all models we need to consider its purpose, the concepts underlying it, and how well its simulations match reality. The purpose of the model, according to the WRC, is "to simulate nitrate movement from the soil zone down to the water table". This means the movement of nitrate from the soil down to the water stored in the aquifer. The model does not explicitly simulate the movement of nitrate in the soil. The agricultural options, however, are very much concerned with the progress of various forms of nitrogen through the soil to the point at which nitrate is washed beyond the reach of the roots of crops.

The concepts underlying the model are also relevant to the way in which the DoE has used it. Within an aquifer, the model simulates the downward movement of peaks of nitrate concentration using a sophisticated set of mathematical flow equations. It does this well, suggesting that the equations are soundly based. But the model is much less sophisticated in its treatment of soil than of aquifers. For the soil, the model relies on a set of empirical rules obtained by relating the peaks of nitrate concentration measured at various depths in the aquifer to "snapshots" of the way in which the land had been used.

The first of the model's rules for the movement of nitrate in the soil allows for a leakage of 280 kilograms of nitrogen per hectare when grassland is ploughed up. (In fact, the loss depends on the age of the grassland.) The second rule concerns leakage when winter cereals are grown, and this rule must be got right because more land in Britain grows winter cereals than any other crop.



Nitrate drainage: Rothamsted estimates (open circles)

Here the model assumes that nitrogen *equivalent* to 40 per cent of the amount applied as fertiliser leaks as nitrate. This is not the same as saying that 40 per cent of the fertiliser nitrogen itself leaks. But it does imply that a cut in fertiliser nitrogen automatically cuts the leakage of nitrate by the same proportion. This assumption clearly has a profound influence on the evaluation of the agricultural options, but it has little scientific backing.

We know of no direct evidence for the "40 per cent" rule. It fails one very simple test. Forty per cent of nothing is nothing, so the rule implies that when farmers do not add fertiliser, no nitrate leaks. Even 100 years ago, researchers knew from observations at Rothamsted that soil carrying an unfertilised crop could, in a year, leak about 20 kilograms of nitrogen per hectare as nitrate. The WRC modellers counter this objection by saying that the model should not be used outside the range of fertiliser applications against which it was developed, a range that did not include no fertiliser. But even within this range, there is no evidence for the "40 per cent" rule. Michael Goss and his team at Rothamsted have for several years measured the amounts of nitrate in the water draining from plots growing crops under various conditions. Their results show no relation between the amount of nitrogen applied as fertiliser in spring and the amount of nitrate in drainage.

When farmers grow spring barley, they leave the soil bare during winter, and more nitrate leaks from it than when they grow

Barnaby's Picture Library

Growing crops soak up nitrogen fertiliser applied in spring

winter wheat. Rodney Dowdell and his colleagues at the Letcombe Laboratory (now closed by government cuts) measured nitrate leaking from the soil in which they grew spring barley over four consecutive years. The researchers applied 80 or 120 kilograms per hectare of nitrogen as fertiliser each year. In both cases, a mere 7 per cent of the nitrate that leaked from the soil came from the fertiliser. The total quantity of nitrate lost was no greater when they added 120 kilograms than when they added no fertiliser at all.

The "40 per cent" rule diverts attention from the real root of the problem, fuelling the popular misconception that nitrate pollution originates from excess fertiliser washed out of farmland. There is, however, little excess to be washed out. This was shown by researchers at Rothamsted when they "labelled" nitrogen fertiliser with nitrogen-15, a heavy isotope of nitrogen, to find out where it went. Winter wheat

* Department of Environment. *The Nitrate Issue*. December 1988. HMSO.

Fatal inaction

It's time to stop procrastinating over nitrate pollution, says Mark Huxham

STOMACH cancer, brain damage, mass fish kills, declining bird populations, tides of scum and the destabilisation of entire ecosystems—all these ills are being laid at the door of nitrates in the water supply. Nitrates are now the most ubiquitous water pollutants in the Western world.

But how should we deal with them? The more notorious environmental villains such as DDT, PCBs and plutonium are so toxic that zero emission of such substances is a clear and feasible policy objective. Nitrates, by contrast, are essential for the normal functioning of a healthy ecosystem. Only when present in excess can they be considered pollutants. Deciding whether levels at a particular site lie within expected, natural variation or are dangerously high, is a subtle and demanding task. It makes a simple "seek and destroy" approach impossible. And once the need for action has been decided, there is the political task of tackling the diffuse inputs of nitrates from agricultural fertilisers, slurry run-off, sewage, atmospheric deposition and other sources.

Despite these problems, many governments are now dealing with nitrates. Some US states have brought in integrated management programmes to control the way that fertilisers—one of the prime sources—are applied. Countries that belong to the European Union are bound by a directive designed to protect public and environmental health by identifying "nitrate vulnerable zones" (NVZs) in which nitrates have reached such dangerous concentrations that plans must be developed to reduce inputs. Where public drinking water is affected, the directive demands that action be taken if nitrates exceed 50 milligrams per litre—the level deemed to be dangerous to human health. But what of other areas?

EU member states are also required to take action if nitrates appear to be causing damage to ecosystems. Environmentalists, scientists and farmers around Europe have had to wait years to see how their governments interpret the legislation. The Netherlands, Sweden and Denmark have all adopted a safety-first approach. Recognising the difficulties of searching for case-by-case evidence, they are establishing nationwide action programmes designed

Woodfall Environmental Images

to prevent discrimination against any particular groups of farmers.

Other EU countries, including Britain, have chosen a different road. Only sites where evidence of ecological damage is clear are designated NVZs. On this basis none has yet been declared in Britain.

Where better to set such a precedent than the country's most intensively studied estuary? The Ythan, a nationally important nature reserve some 20 kilometres north of Aberdeen on Scotland's east coast, is the leading contender for designation. Forty years of data show rising nitrogen concentrations in the water. Huge mats of algae now coat the mud flats in summer, displacing wading birds and killing many of the invertebrates that underpin the food chain. This has convinced the Scottish Environment Protection Agency, along with scientists working on the site, that the estuary is polluted.

But sceptics point out that nothing is certain. No one can prove beyond all doubt that the algae have grown because of the nitrogen. Perhaps the algae was always there, but has only been recorded recently? Maybe it spread because of a change in climate or tidal patterns?

Even the best scientific assessments will always leave room for such doubts. Which is why environmentalists call for a precautionary approach—giving the environment the benefit of the doubt in cases of scientific uncertainty. Because nitrates are a natural part of the ecosystem, this cannot mean "eliminate the suspect at source". Instead it implies that action should be taken as soon as the balance of probabilities implicates nitrates, rather than waiting for proof beyond reasonable doubt.

The last government refused to designate the Ythan because there was no "incontrovertible proof". Its successor, elected in 1997, signed Britain up to international agreements that enshrine the precautionary principle. This makes its stance over nitrates particularly puzzling. Last September it refused NVZ status to the Ythan because the evidence of nitrate pollution is "not conclusive". This just won't wash. Complex pollution cases can never be decided conclusively. It's time to stop using uncertainty as an excuse for inaction on nitrates. □

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The effect of organic amendments on the restoration of a disturbed coastal sage scrub habitat.

Thomas A. Zink and Michael F. Allen

Restoration Ecology 6:52-58. 1998

Since at least 1980, conservation and restoration biologists have expressed concern that high concentrations of soil NO3- and NH4+ may favor introduced annual weeds (e.g., annual ryegrass, wild oat) over California native plants, including herbaceous species, shrubs and trees. Lignin-rich organic mulches may promote survival and growth of newly planted trees and shrubs, in part by suppressing some species of weeds. A better understanding of these soil-plant dynamics may help determine best practices for establishing hedgerows and diversifying field edges in agricultural settings.

At the Santa Margarita Ecological Reserve near Temecula, San Diego County, Calif., researchers Zink and Allen used a randomized complete block design with plot size 1.0 x 0.5 m to evaluate effects of organic mulches on survival and growth of seedling California sagebrush (Artemisia californica). The three treatments were: 1) pine bark; 2) oat straw; 3) no mulch (control). Response variables were assessed on eight occasions from February 1993 to June 1995, including seedling survival and estimated above-ground volume of California sagebrush plants, soil total N, soil N03-, several indices of soil microbial activity, and soil organic matter. Growth of potentially competing annual vegetation (e.g. wild oat [Avena fatua]) was not measured. Separate analyses of variance (ANOVA) were conducted for data from each date, with Fisher's protected least significant difference test used for detected differences among pairs of means.

A summary of the data shows that:

- Pine-bark mulch plots showed the greatest sagebrush survival rates over the course of the experiment (66% survival as contrasted with 42% for oat-straw and control plots).
- California sagebrush growth was also greatest in pine-bark mulch plots.
- Both mulches had significantly lower soil NO3- concentrations on six of eight sampling dates.
- From January 1994, mulch-amended plots had greater active fungal biomass than control plots.
- There were no strong nor consistent differences in bacterial biomass among the three mulch levels.
- Soil organic matter content did not differ among the three treatments for the first six months; from January 1994 through the end of the research, organic matter content increased significantly under the bark-amended plots compared to control plots. No change in organic matter was detected under the oat-straw treatment.

The authors attributed increased survival and growth of California sagebrush to reduced NO3- availability in the mulched plots and suggested that this mediated competition by wild oat and other introduced annual weeds for other nutrients and water. The authors also mentioned the role of mulches in conserving soil moisture as a possible factor influencing plant growth. As no measurements were made of potentially competing vegetation nor of soil moisture, the mechanisms for the improved survival and growth of California sagebrush remain speculative.

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DEC. 603

Contributed by Robert L. Bugg

Dirty groundwater runs deep

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Spreading pollution is increasingly fouling Britain's underground water reserves

Fred Pearce

THE Oxfordshire village of Blewbury is built on a water meadow, with springs bubbling up everywhere and brooks babbling down the lanes. "It's a lovely place," says resident Wendy Gilford, watching the ducks on the village pond. "Such a shame to think the springwater is full of poison from Harwell."

The Harwell Science and Engineering Centre, formerly the UK Atomic Energy Research Establishment, is only six kilometres from Blewbury. It is one of Britain's largest and oldest nuclear establishments. But its 3.5 square kilometres are now dotted with mothballed nuclear reactors, radioactive waste stores and pits where waste chemicals and solvents have been poured into the earth during past decades.

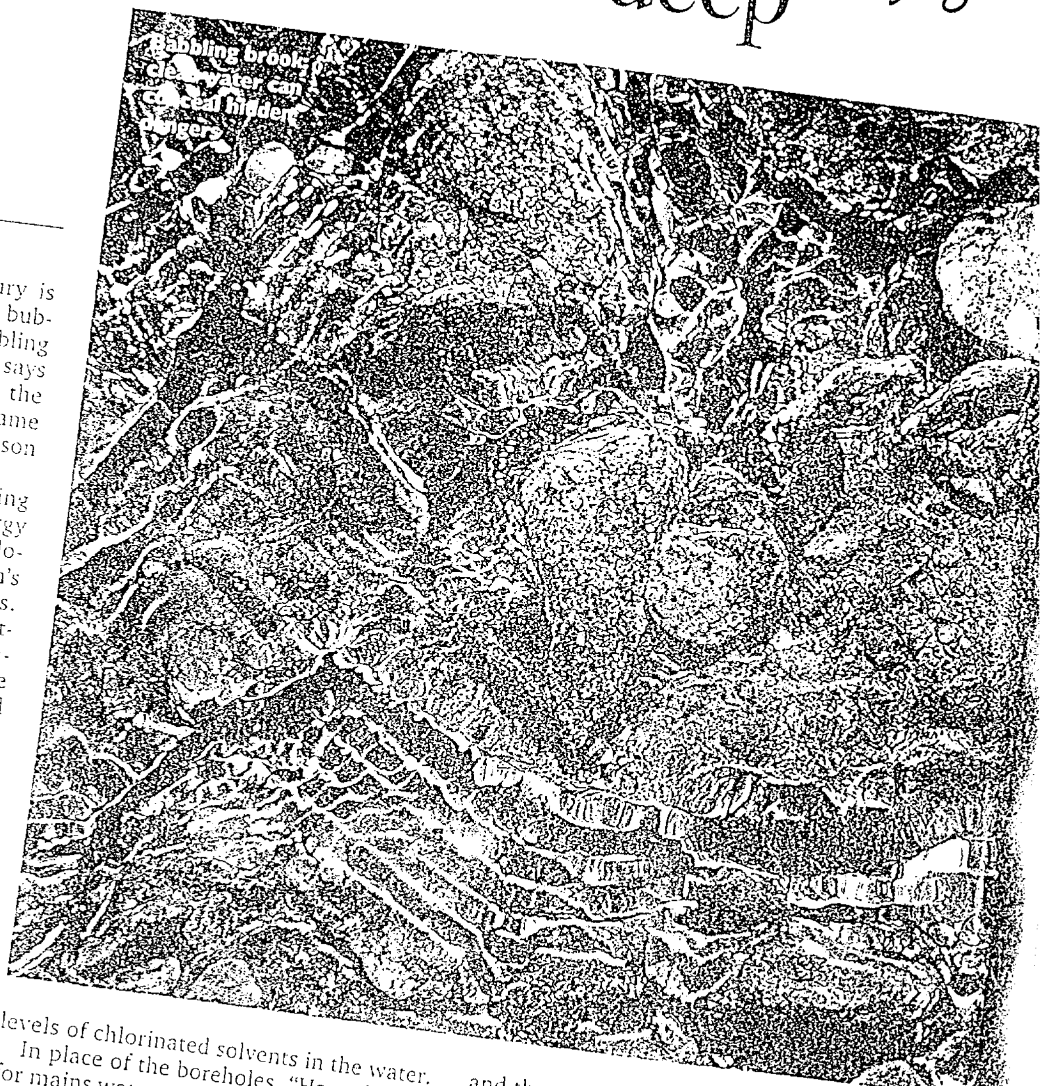
The site is being cleaned up now. Some of the land is to be sold off for housing and an industrial estate. This month AEA Technology, a large part of the operation, goes up for sale as the latest phase of the government's privatisation programme.

AEA Technology has been cleaning up contaminated soil round the edge of two large waste dumps—known euphemistically as the Southern and Western Storage Areas. It pumps up the water and strips it of a range of toxins, especially persistent chlorinated solvents. The purpose, according to company scientist Lori Fellingham, who wrote to local residents in March, is "to remove any new contaminants before they have an opportunity to disperse". In two years, says Fellingham, some 3 tonnes of contaminants have been extracted from the water.

But there is much more pollution below the ground that will not be reached by the cleanup. And these contaminants are gradually spreading beneath the fields and villages of south Oxfordshire and bubbling up in springs, such as those at Blewbury.

Wells and boreholes owned by water companies, farmers, hotels and private houses have been shut in the past three years because of the contamination. Surveys of some private wells by the former National Rivers Authority revealed high levels of chlorinated solvents in the water.

In place of the boreholes, "Harwell pays for mains water to be piped in from further away," says Gilford, a former employee of Harwell. The centre is the area's biggest employer. After she retired, Gilford founded the Blewbury Environmental Research Group to investigate the pollution from Harwell.



Babbling brook: clear water can conceal hidden dangers

Without prejudice

Nick Hance, a spokesman for the Atomic Energy Authority at Harwell, is reluctant to accept that the centre is responsible for the problem. "Pollution can go off in all sorts of directions, so proving things is very hard," says Hance. However, he confirms Gilford's story. "We have paid for some private boreholes to go onto the mains. The only condition is that we do it without prejudice. We don't accept liability."

The contamination levels in Blewbury and the surrounding villages are still small compared with the levels near the dumps. Around the dumps, up to 39 000 micrograms of chloroform per litre and 13 000 micrograms of trichloroethane (TCA) have been found. But villagers fear that as the years pass, the pollution will spread far beyond the confines of Harwell.

Until quite recently Harwell denied any role in the pollution. In a letter to Gilford in 1992, AEA Technology's head of safety suggested that the pollution came from an RAF munitions dump which previously occupied the site. This dump was shut in 1946, when the site was handed over to the nuclear researchers. But in 1993 Fellingham told a conference in London that the disposal of solvents "from the end of World War II through to 1977" at the two dumps had contaminated the aquifer.

The nuclear industry is not the sole offender, however. "Harwell is not alone

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Green Grass, Cool Climate?

Climate researchers and ecologists suspect that nitrogen, pumped into the environment from the burning of fossil fuels and the use of agricultural chemicals, is a double-edged sword. It may be "fertilizing" ecosystems, causing plants to sop up ever more carbon dioxide and slowing the atmospheric buildup of this greenhouse gas. But it also appears to favor the growth of weed plants at the expense of native species. Now a new study not only confirms this harmful ecological effect but suggests that it undermines any potential climate benefits.


ANN B. SWENGEL/VISUALS UNLIMITED

Natural state. Native prairies store more carbon in soils than do grasslands dominated by invasive species.

On page 1720, ecologists David Wedin of the University of Toronto and David Tilman of the University of Minnesota report that while, in the short term, nitrogen inputs spur growth, inducing plants to fix more carbon in their tissues, over the long term, added nitrogen indeed pushes the mix of plants toward fast-growing, invasive species that aren't efficient at fixing carbon in soils. The result: A grassland's biodiversity drops, and its overall ability to sequester carbon soon levels off. "This suggests that there are limits on how effective this added nitrogen is going to be at slowing carbon dioxide buildup," says ecologist Don DeAngelis of the U.S. Geological Survey.

Documenting long-term effects of the extra nitrogen on Earth's carbon cycle hasn't been easy. Ecologists, says DeAngelis, tend to work with "plants in a pot," which aren't very good at replicating what happens in actual ecosystems. But a research team led by Tilman devised an experimental system from three once-abandoned fields, which they divided up into 162 4-by-4-meter plots. The researchers dosed the plots with varying quantities of nitrogen fertilizer—plus lime so the nitrogen wouldn't acidify the soil—then measured changes in both plants and soils.

Over the past 15 years, the Tilman team—as well as Dutch and British groups studying heathlands—have published a number of studies that have sounded an alarm about the effects of widespread nitrogen deposition on biodiversity. To convert sunlight and carbon dioxide into carbon-based plant matter, plants need nitrogen. But as the Tilman group demonstrated, adding lots of nitrogen caused a shift from native species—such as little and big bluestem grasses, which don't need much nitrogen to

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the recovery of the native enzymatically active tetramer (6). Alternatively, interaction with the individual chaperones Hsp90, Hsc70, Hsp70, or Cyp-40 does not lead to refolding of the denatured substrate to its native state, but rather leads to an apparent collapse of the denatured β-Gal to a stable proteolysis-resistant nonnative intermediate that is subsequently responsive to the refolding activity of Hsp70 and Hdj-1. We suggest that the interaction between p23 and denatured β-Gal represents a distinct activity that results in the maintenance of the β-Gal in a proteolysis-sensitive, yet soluble, nonnative state that can be converted to the native state upon addition of Hsp70 and Hdj-1. These studies identify new members of the family of proteins that act as molecular chaperones. The involvement of multiple proteins with apparently redundant chaperone activities in heteromeric complexes may provide diversity and specificity in the regulation of the biological activity of associated protein substrates. This may have implications for pathways of hormonal regulation, signal transduction, and immunosuppression (11).

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10. The folded state of denatured β-Gal diluted int BSA, Hsc70, p60, Cyp-40, Hdj-1, or p23 was char acterized by electrophoresis on native 4% polyacryl amide Na-borate (0.1 M sodium acetate and 0.1 M boric acid) gels at 4°C at 1 mm/min (6) or by sepa ration of the soluble and insoluble fractions of β-Ga by centrifugation at 13,000 rpm for 5 min and separation with 10% SDS-PAGE. The β-Gal was detected by protein immunoblot analysis after electroblotting onto nitrocellulose, incubation with an antibody to β-Gal (anti–β-Gal), and detection by ECL (Amersham).
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Influence of Nitrogen Loading and Species Composition on the Carbon Balance of Grasslands

David A. Wedin* and David Tilman

In a 12-year experimental study of nitrogen (N) deposition on Minnesota grasslands, plots dominated by native warm-season grasses shifted to low-diversity mixtures dominated by cool-season grasses at all but the lowest N addition rates. This shift was associated with decreased biomass carbon (C):N ratios, increased N mineralization, increased soil nitrate, high N losses, and low C storage. In addition, plots originally dominated by nonnative cool-season grasses retained little added N and stored little C, even at low N input rates. Thus, grasslands with high N retention and C storage rates were the most vulnerable to species losses and major shifts in C and N cycling.

Humans have dramatically altered the cycling of nitrogen on Earth, doubling the natural rate of N fixation and causing atmospheric N deposition rates to increase more than tenfold over the last 40 years to current values of 0.5 to 2.5 g N m^{-2} $year^{-1}$ in eastern North America and 0.5 to 6.0 g N m^{-2} $year^{-1}$ in northern Europe (1). Because N is the primary nutrient limiting terrestrial plant production, N addition is causing shifts in plant species composition, decreases in species diversity, and changes in food-web structure in terrestrial ecosystems (2–5). This N-driven terrestrial eutrophication parallels phosphorus-driven eutrophication in lakes. Increased N deposition may lead to greater C storage in soil organic matter and vegetation, thus providing a sink for CO_2 and potentially explaining the globally "missing C" (6). Despite this, almost no experimental data exist on changes in ecosystem C in response to long-term N addition in nonagricultural ecosystems; rather, effects on C stores have been estimated from models, giving divergent predictions (6).

We present results of 12 years of experimental N addition to 162 grassland plots in three N-limited Minnesota grasslands that varied in successional age, total soil C, and plant species composition (7, 8). The youngest field (Field A) was dominated by vegetation with the C_3 photosynthetic pathway, primarily nonnative "cool-season" grasses and forbs, whereas the two older fields (Fields B and C) were dominated by native C_4 "warm-season" prairie grasses. Because other potentially limiting nutrients were supplied and soil pH was controlled, our study addresses the eutrophication effects of N loading while controlling for acidification and related biogeochemical effects that might also affect natural ecosystems (9, 10).

Nitrogen loading dramatically changed plant species composition, decreased species diversity, and increased aboveground productivity in these plots (2, 7, 11). After 12

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support the conclusion that microbial immobilization of mineral N is a major factor regulating N retention (*10, 23, 25, 30*).

Our analyses indicate another potentially important factor regulating soil NO_3^- pools in these grasslands. Plant species diversity remained a significant negative correlate of soil NO_3^- in a multiple regression model that accounted for the effects of litter C:N ratio and N addition rate (*29, 31*). This suggests that complementary spatial and temporal patterns of nutrient uptake associated with high plant-species diversity or functional group diversity also play a significant role in ecosystem N retention (*32*).

We conclude that the shift from N immobilization to mineralization, a threshold determined by microbial resource requirements and the C:N ratio of an ecosystem's detrital biomass, creates an inherent nonlinearity in the response of these grasslands to chronic N loading. In our study, species shifts in the vegetation at low levels of N loading appear to be driving such a nonlinear response of the N cycle (*4, 15*). In addition to shifts in species composition, the loss of diversity, per se, during eutrophication may contribute to decreased N retention in grassland ecosystems subjected to atmospheric N deposition (*31*).

Two patterns emerged for the net change in total ecosystem C stores after 12 years (*12, 21*). First, although total C stores differed significantly among the three fields across the experimental N gradient, differences were greater at the low end of the gradient (*33*). At the high end of the N addition gradient, all fields were converging on total C stores of roughly 4000 to 5000 g C m^{-2}. Second, total C stores increased significantly at low N addition rates in the C_4-dominated fields (Fields B and C) but not in the C_3-dominated field. Averaging across the three lowest N addition levels (1, 2, and 3.4 g N m^{-2} $year^{-1}$), total ecosystem C increased 21% (545 g C m^{-2}) in Field B, which had lower soil C initially, 10% (445 g C m^{-2}) in Field C, and only 1% (27 g C m^{-2}) in Field A. In contrast, theoretical estimates of C storage for humid temperate grasslands in response to climate change, direct CO_2 enrichment, or both range from 3% to −3% (*34*). Carbon storage resulting from anthropogenic N inputs, although highly dependent on grassland type, may be markedly greater than C storage in response to other components of global change.

Finally, we determined the net long-term change in total ecosystem C per unit of added N over our 12-year study. In regression analysis, there was significantly lower C storage (g C/g N) at N addition rates <5 g N m^{-2} $year^{-1}$ for Field A than for Fields B and C, as well as a significant effect of N addition rate and a significant field-by-N-addition interaction (Fig. 4) (*35*). Without field as a categorical variable, plot C_4 biomass was the best single predictor of C storage (*35*).

At the lowest N addition rates (1 and 2 g N m^{-2} $year^{-1}$), the C storage rate averaged 24.3 g C/g N (n = 24, SE = 7.6) in Fiel B and C (Fig. 4). Although we know of comparable values from other long-term e periments, our value of 24.3 g C/g N is lo compared to most model estimates of net C storage in response to atmospheric N dep osition, which range from 17 to >100 g C/ N (*6*). This difference probably relates t ecosystem type. In our two C_4-dominated grasslands, 63% of the long-term C storage was in soils, which had a C:N ratio of roughly 11. Globally, woody vegetation with a higher C:N ratio becomes a more significant C sink.

Estimates of C storage in response to N loading are the product of two terms: net C storage per unit N retained and the N retention rate. In simulations with the CENTURY model of long-term C budgets for *S. scoparium* monocultures in our soils and climate, we found a long-term C storage rate of 22 g C/g N input from atmospheric deposition (*36*). Thus, our empirical and modeling estimates of C storage (g C/g N) were very similar for low N addition plots in Fields B and C, where N retention rates were ~100%.

In contrast, the model (*36*) did a relatively poor job of predicting C storage rates for Fields B and C at medium to high N inputs and Field A across the N gradient. CENTURY simulations predicted a long-term C storage rate of 10 g C/g N for *A. repens* monocultures, the dominant C_3 grass in Field A and in high-N plots. However, no net C storage was observed for Field A at low N inputs, and at the high end of the gradient, net long-term C storage across all fields converged on roughly 4 g C/g N (Fig. 4). These results underscore the need for a clearer understanding of why N retention rates differ among ecosystems if ecologists are to make reasonable estimates, whether on local or global scales, of C sequestration in response to N loading.

The grassland types best able to retain added N and sequester C were also the types most vulnerable to N eutrophication through losses of diversity, changes in plant species composition, and the resultant changes in C and N cycling. Thus, N-caused shifts in species composition limit the ability of temperate grasslands to serve as significant long-term C stores. In our fields dominated by C_4 prairie grasses, shifts in species composition at relatively low N addition rates led to decreased biomass C:N ratios and decreased N immobilization potential, and, consequently, increased soil NO_3^- concentrations, high N loss rates, and low C sequestration rates (g C/g N). The nonlinear or threshold-dependent response that we observed in response to chronic N loading appears to have two causes: species shifts in response to N eu-

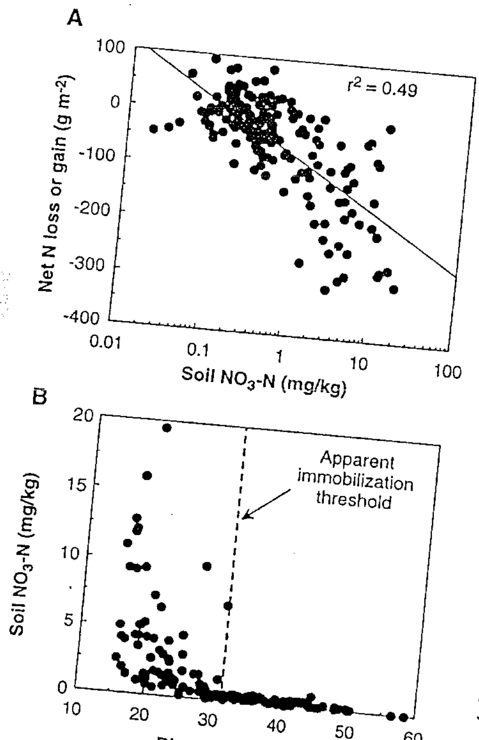

Fig. 3. (**A**) The relationship between net N losses or gains (the change in total system N minus the sum of experimental N additions) and seasonal average soil NO_3^- concentrations in 162 experimental plots. The equation for the fitted curve (note log scale) is N_{lost} = (−75.56) − [94.89 × log(NO_3)]. (**B**) The relationship between soil NO_3^- and the C:N ratio of plant biomass (aboveground dead biomass plus belowground biomass). Vertical line represents a biomass C:N ratio of 32.

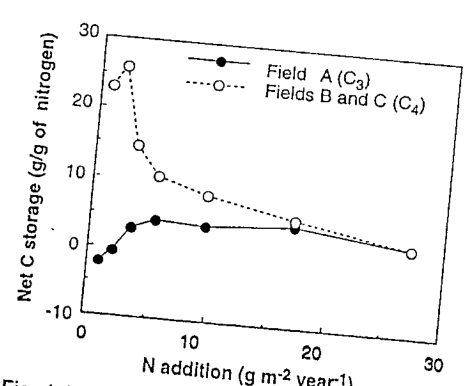

Fig. 4. Net C storage per unit experimentally added N after 12 years. Because C storage rates (g C/g N) did not differ significantly between Fields B and C (*34*), overall treatment means for the two C_4-dominated fields are presented.

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1,2 Dibromo-3-Chloropropane (DBCP) and Ethylene Dibromide (EDB) in Well Water in the Fresno/Clovis Metropolitan Area, California

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ABSTRACT. Ground-water contamination with the pesticides 1,2 dibromo-3-chloropropane (DBCP) and ethylene dibromide (EDB) affects Fresno/Clovis city in California. The spatial and temporal distribution of DBCP and EDB in public wells in Fresno/Clovis was examined, using mapping and time-series analyses of chemical test results, during the time periods 1979–1980 and 1992–1993. Health risks were estimated from mean concentrations, lifetime cancer risks were estimated, and monitoring and control programs were reviewed. Mean DBCP concentrations in selected wells declined from 0.56 ppb in 1979–1980 to 0.18 ppb in 1992–1993. Closure of wells and wellhead filtration caused levels to be reduced further (i.e., to 0.06 ppb). Mean EDB concentrations declined from 0.25 ppb to 0.15 ppb during the same time periods. The estimated lifetime cancer risk for DBCP was 1 excess death per 125 000 population in 1992–1993, but this risk varied within the city. The risk for EDB was 1 excess death per 2.2 million. Recommendations were made for the modeling of pesticide movement in ground water and for epidemiological studies.

THE RAPID GROWTH of California's population, agriculture, and industry and the relative scarcity of water resources in much of this state have made the supply, delivery, and regulation of drinking water an important and sensitive issue. Approximately 30% of California's population obtain their drinking water from wells. Numerous agricultural pesticides, industrial chemicals, and household chemical products (particularly pesticides and herbicides) have been found in drinking-water wells throughout California. In California, the most common contaminants found in the 14 000 public wells tested for 380 different industrial, agricultural, and naturally occurring chemicals between 1984 and 1989 were nitrate and the pesticide 1,2 dibromo-3-chloropropane (DBCP). Levels of these pesticides exceeded the maximum contamination level (MCL) in 2.1% and 1.4%, respectively, of all wells. The MCL for ethylene dibromide (EDB) was exceeded in an additional 0.11% of the wells.[1–3]

The Fresno/Clovis metropolitan area was of considerable interest for a case study of well-water contamination by pesticides. Nationwide, Fresno County has been the leading agricultural producer since the early 1950s, and Fresno/Clovis is 1 of the 10 large urban areas in the United States that depends exclusively on well water.[4] All major crops cultivated in the Central Valley, including grapes, citrus, many stone fruits, nuts, vegetables, grains, and cotton, are regularly fertilized and treated chemically for pests and weeds.

The pesticide DBCP, a soil fumigant used to control

1979–1980, during which time only one test was available. Time trends of DBCP in selected wells were based on four quarterly test results per year. The relative health risks of DBCP and EDB in community wells were estimated, based on the concentrations of these chemicals in the Fresno and Clovis water-supply systems and on their estimated lifetime cancer risks.[2] No information was available about the degree of mixture of water from different wells; therefore, DBCP and EDB concentrations at the tap were unknown. No attempt, therefore, was made to correlate DBCP and EDB concentrations with cancer deaths reported. Whorton et al.[11] reported this problem in rural Fresno County.

Results

The Fresno/Clovis area: physical environment and pesticide use. Contamination of wells with DBCP was reported initially in Fresno County in 1979; reports about EDB were first made in 1983.[7,23] Between 1970 and 1977, almost 600 000 pounds of DBCP were applied—more than in any other county in California, except San Joaquin.[24] Available data indicate that the usual dosage of DBCP in Fresno County was quite high (i.e., 20–80 pounds per acre), and soil injection was generally preferred over irrigation because it was very effective in sandy soil.[6,21] Very strong associations were noted between the distribution of DBCP in wells and vineyards in eastern Fresno County.[20,21]

Two factors have been instrumental in increasing the risk of well-water contamination by DBCP and EDB within the Fresno/Clovis urban area: (1) the rapid expansion of the Fresno/Clovis metropolitan area during recent decades into what was agricultural farmland has precipitated the location of new wells in contaminated aquifers near the city boundary; and (2) a cone of depression in the ground-water table has formed under the city as a result of intensive, continuous pumpage above the recharge rate obtained from rain, canal seepage, and infiltration at the city's recharge basins. Annual pumpage between 1980 and 1989 exceeded recharge through the recharge basins nearly five-fold. In contrast, in rural Fresno County, pumpage for domestic purposes and irrigation was approximately equal to the recharge from canal seepage and excess irrigation water.[20] Currently, the water-table depth is approximately 80–120 ft (24–37 m) in the Fresno/Clovis metropolitan area, but is only about 30–70 ft (9–21 m) in surrounding rural areas.[20] The deepening cone has diverted the flow pattern of pesticide-contaminated ground water, which originated in agricultural areas east and south of Fresno, from the normal northeast-southwest direction toward the northwest (Fig. 1). The depression also increased the lateral flow rate—above the usual rate outside the cone—of pesticide-contaminated ground water into the city.[20,22]

Monitoring of water quality. The cities of Fresno and Clovis monitor all public drinking-water wells, a policy that is consistent with the water-quality regulations of the California Office of Drinking Water.[2] Therefore, wells are sampled routinely, and they are tested at least once every 3 y for general minerals, physical properties, and most inorganic and organic chemicals; if one or more of these contaminants are found, testing occurs more frequently. All wells in Fresno and Clovis are considered to be vulnerable to DBCP and EDB contamination; therefore, they are sampled every 2 y. The water quality monitoring program implemented by the City of Fresno at the end of 1992 specified that 122 wells were to be sampled every 2 y for DBCP and EDB, 78 wells were to be sampled every 3 mo, and 13 wells were to be evaluated monthly (M. McIntyre, City of Fresno, personal communication).

Changes in water-quality standards have also influenced the frequency of sampling of individual wells, further impeding the analysis of time-series data. In 1979, the California Department of Health Services set an action level of 1.0 ppb for DBCP; in 1979, it adopted a state MCL of 0.2 ppb, which was adopted subsequently by the U.S. Environmental Protection Agency.[2]

Control programs. During recent years, various remedial and rehabilitative measures have been implemented in Fresno and Clovis to reduce well-water contamination. The intervention measures implemented to date have been closure of most wells that contain chemical concentrations above the MCL, deepening and resealing of wells, installation of monitor wells, and wellhead treatment. The new Fresno Metropolitan Water Resources Management Plan calls for installation of larger distribution pipes and tanks to facilitate the dilution of contaminated water with uncontaminated water, increased recharge of the aquifer through use of uncontaminated canal water for landscape irrigation, wellhead treatment of new and existing wells, creation of a hydrological barrier by recharging the down-gradient DBCP-free aquifer with clean canal water, and a conservation program.

By the end of 1993, 23 of the 125 wells found to contain DBCP had been closed because the MCL of each exceeded 0.2 ppm. Ten wells (including 4 of the 23 referenced above) had been closed because they exceeded the 0.02 ppb EDB MCL. Twenty-eight wells had been deepened and resealed. Seven GAC wellhead treatment systems were installed, and plans specified that an additional 40 filtration systems be installed. Granulated activated carbon filtration removes both DBCP and EDB from well water to levels below 0.01 ppb[25] (M. Reitz and M. McIntyre, Boyle Engineering, unpublished report).

Spatial distribution of DBCP. In 1992–1993, 87 of the 302 (28.8%) active wells and 39 of the 43 (88.9%) closed wells in the Fresno/Clovis urban area had detectable levels of DBCP. Mean DBCP concentrations in 6 of the active wells (all new wells are being monitored by DBCP) and in 25 of the closed wells were above the 0.2-ppb MCL. The most contaminated well (mean concentration = 2.84 ppb) was a closed well in east Fresno. All wells that contained high levels of DBCP were located in eastern and southeastern Fresno and in Clovis, within and down-gradient from the DBCP plumes along the city limits (Fig. 1).[20,21] The levels of contamination decreased toward the north-

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western and western parts of the city. The overall spatial distribution of DBCP did not change significantly between 1979 and 1980 and between 1992 and 1993. Nonetheless, concentrations of DBCP in 7 wells that exceeded the MCL in 1979–1980 were lower in 1992–1993, and 9 wells with low DBCP levels in 1979–1980 exceeded the MCL in 1992–1993. The location of all but one of the latter wells 2–3 km down-gradient from wells already closed in 1979–1980 indicated that DBCP moved in ground water approximately 2 km during these 13 y (Fig. 1).

Depth of wells. Well depth, considered an important factor in DBCP occurrence in well water,[22,26] was associated only weakly with DBCP concentration in 61 wells for which well-construction data were available ($R = -.069$). The average depth of the Fresno/Clovis wells was 91.5 m in 1993 (range = 29–177 m). In 1993, 5 of the 7 wells in our sample of 88 wells deeper than 140 m had detectable DBCP; 4 of these 5 had levels between 0.2 and 1.0 ppb. The predominantly sandy and permeable soils of the Fresno/Clovis area are approximately 60–80-m deep before they give way to silt and clay, thus facilitating the downward movement of DBCP into the intake area of many wells.[22] The relatively thin clay lenses in the Fresno area do not appear to stop percolation; in fact, they may even constitute a reservoir from which DBCP is released slowly.[18]

A slightly stronger negative correlation was found between DBCP concentration and depth of the uppermost perforations of well casings ($R = -.1534$). This, together with the fact that most well perforations originated some distance below the water table, corroborated the finding that DBCP tended to present primarily on or near the top of the water table.

Temporal patterns. Comparison of 227 wells for which DBCP data were available for both 1979–1980 and 1992–1993 showed that most wells with detectable DBCP in 1979–1980 were still contaminated, but typically at lower levels, in 1992–1993. The closure of 25 wells and the installment of GAC wellhead filtration systems on another 5 wells between 1979 and 1993, however, reduced DBCP concentrations significantly. Nevertheless, several active wells in Clovis and Fresno were found with detectable DBCP levels for the first time in 1992–1993 (Fig. 1). Schmidt[22] predicted DBCP occurrence correctly for 11 of 12 wells in Fresno in 1982–1983; he considered distance to DBCP plumes, direction, speed of ground-water flow, and other local hydrological and geological conditions. Additional factors in the spatial and temporal distribution of contaminants in urban wells are seasonal and daily (day-to-day and day/night) variations in pumpage, associated fluctuations in ground-water level, and daily and monthly variations in the times of sample collection.[21,22] Comparisons of test results for the same DBCP samples, obtained by the California Department of Water Resources in Fresno from different laboratories, revealed considerable differences in many cases, thus indicating variations in laboratory procedures.

Two simple time-trend analyses were conducted to determine the decline of DBCP in well water between 1979 and 1993. In the first analysis, the mean concentration of DBCP declined in the 20 highly contaminated wells (i.e., without GAC filters). In eastern and southeastern Fresno and in Clovis, mean concentrations declined from 0.56 ppb in 1979 to 0.18 ppb (67.9% decline) in 1993; in 17 lightly contaminated wells in north, central, and west Fresno, a 49.9% decline (from 0.07 ppb to 0.04 ppb) was noted (Fig. 2). The greater decline of concentrations in wells near the eastern city limits, compared with wells in the down-gradient more-distant central and northern parts of Fresno, suggested that the DBCP plume east and south of the city had become relatively more diluted by natural and artificial recharge. Such a result also suggested that, in the absence of DBCP, a degrading had occurred since 1977 and that the front edge of the plume had been moving west and north across the urban area. This was supported further by the fact that the decline of DBCP in Fresno/Clovis wells was also smaller than the four- to five-fold declines in DBCP levels reported during the same time period in two comparable studies of small- to medium-sized community-well systems located in rural eastern Fresno County and nearby Merced County.[20,27] Well pumping from shallow wells, irrigation with DBCP-contaminated water, consequent loss of DBCP through volatilization, and seepage of uncontaminated canal water may have contributed to the greater decline of DBCP levels in rural and peripheral urban areas, compared with pumpage from deep wells in Fresno/Clovis.[20] The increase in DBCP between 1987 and 1989 in the highly contaminated wells appeared to be the result of (a) the combined effects of increased rainfall and increased irrigation (i.e., when more surface irrigation water was available); and (b) consequent increases in DBCP infiltration, after the drought in California in the early and mid-1980s, from overlying soils. Mayer et al.[13] reported a significant correlation between EDB time series and precipitation in Washington State. Similarly, the decreases in both the ground-water level and DBCP in Fresno/Clovis after 1990 were consistent with the return of drought conditions.

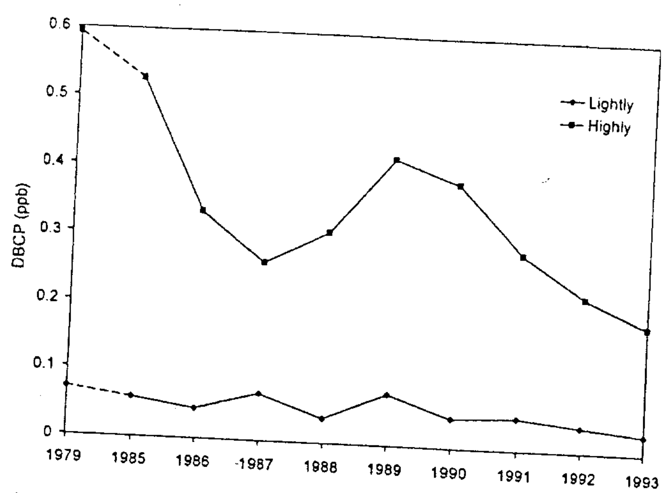

Fig. 2. Mean DBCP concentrations in 20 lightly (i.e., below MCL) and 17 highly (above MCL) contaminated wells in Fresno/Clovis in 1979 and in 1985–1993.

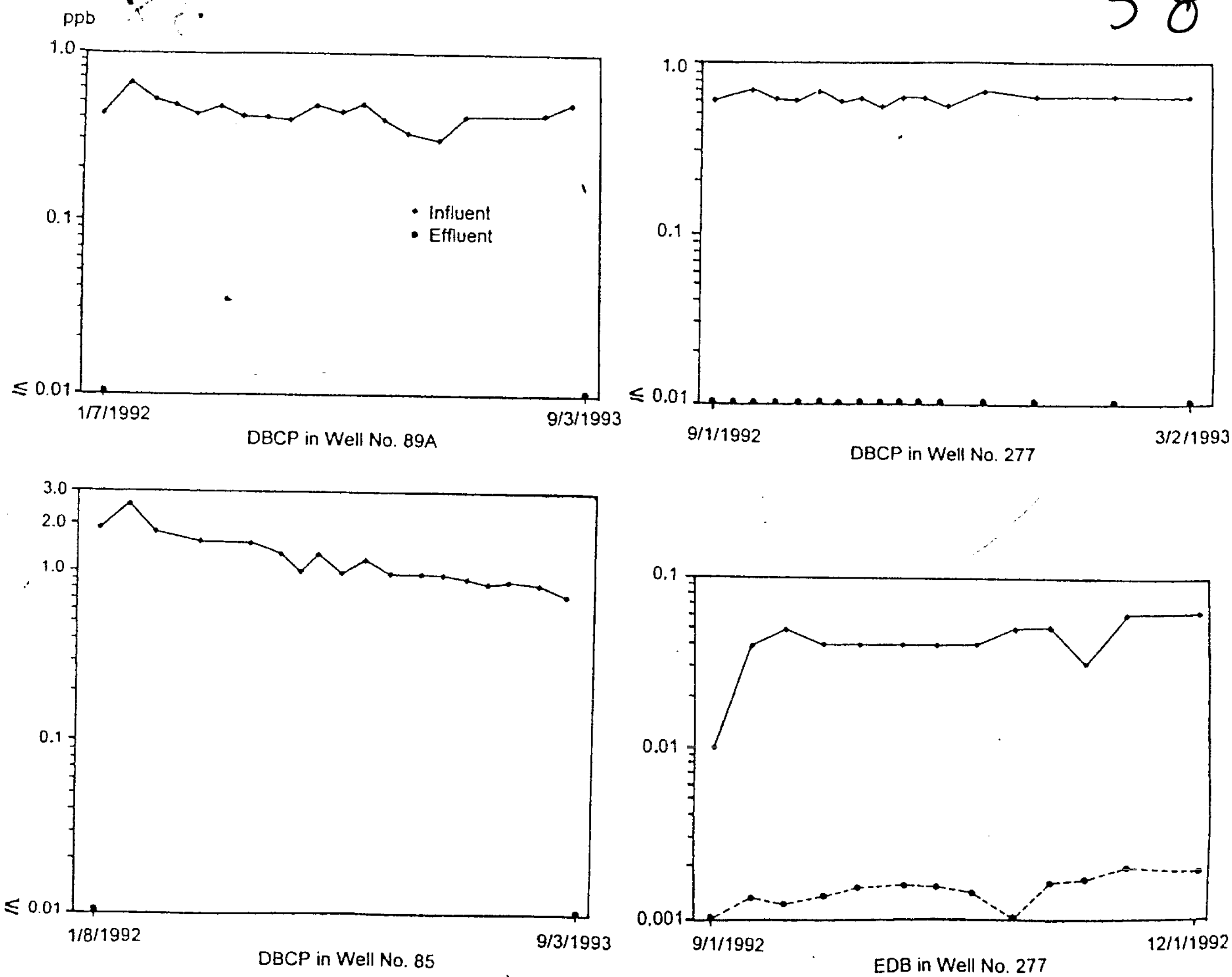

Fig. 4. Weekly DBCP concentrations in unfiltered- (influent) and filtered- (effluent) water wells 89A and 277 in Fresno, monthly DBCP concentrations in well no. 85, and weekly EDB concentrations in well no. 277.

GAC filtration reduced the concentrations of EDB and DBCP in the individual influent samples by more than 90% and 98%, respectively (Fig. 4).

Day-to-day changes in DBCP concentrations were observed for many wells. In the closed Clovis well no. 12, the highest concentrations of DBCP were recorded during the first day of the first two of five daily pumping/testing periods, and this corroborated the finding by Schmidt,[22,26] who reported that DBCP and nitrate concentrations in samples are affected by preceding pumping time. Daily variations were recorded during all five test series (Fig. 5). Significant variations also occurred between concentrations identified during mornings and afternoons for several test wells; this finding was associated with variations in pumpage.[21] These results indicated the lack of a time-specific sampling plan for scientific monitoring of contaminants in wells, a problem noted also by other investigators in Fresno.[20,22]

Cancer risk. No conclusive cancer-risk assessment was possible for Fresno/Clovis because there was a lack of information about the community water-distribution

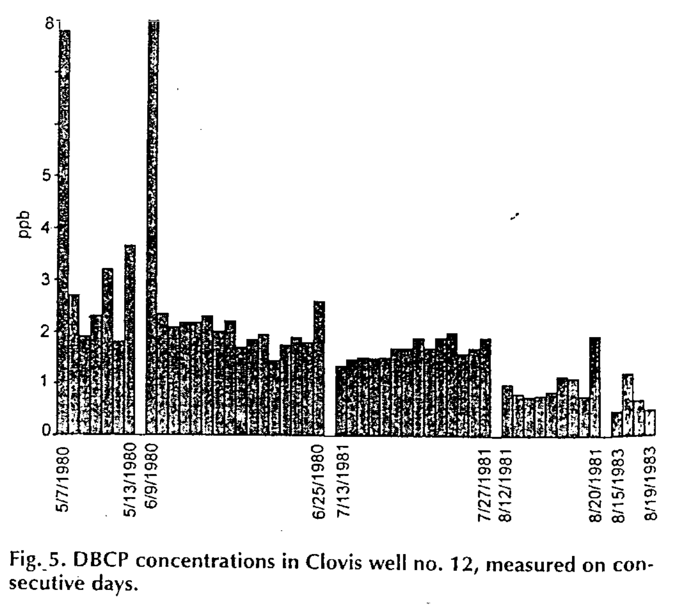

Fig. 5. DBCP concentrations in Clovis well no. 12, measured on consecutive days.

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and temporal models of DBCP, EDB, and other chemicals originating in nonpoint-source contamination.[3,14,18,22,29] Geographical information systems are particularly valuable for the development of ground water protection programs.[30]

The significant reductions in the concentrations of DBCP and EDB from well closure and wellhead treatment must be considered in future epidemiological studies. In the quantification of health risks—particularly cancer risk—of individual contaminants, the changing nonaquatic carcinogenic environment of urban areas must be considered as well. In addition, selection of study populations should be made on the basis of past exposure (i.e., occupation, lifestyle, duration of residence, and travel history).

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Twenty-First Century Forces Going Counter To A Sustainable Food System

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While global food supplies are increasing, several major trends in today's growth and development environment are putting enormous pressure on the sustainability of our food system. The first is the global marketplace demand for a constant supply of highly uniform food originating from as few sources as possible. This forces farmers in geographical areas to concentrate on a single commodity, or a small group of commodities. From an industrial process viewpoint one maximizes efficiency of investment by specializing. Such a trend is a disaster from the standpoint of landscaping-level resource use and with respect to ecosystem stability and resiliency. Crop diversity over time and space is critical to long term biological and biogeochemical stability. Current market forces are driving farms to a level of specialization and geographical concentration that is well below optimal diversity levels for biological stability and efficient nutrient inputs, are less efficient nutrient and residue recycling. These systems require far higher levels of pesticide and nutrient inputs, are less efficient in containing residues and other production materials, and result in higher environmental loading. Such simplistic "factory" systems provide both lower levels and lower quality of ecosystem services (water cycling, pest suppression and biodiversity) than is required for good landscape management. Farms are production "factories" without walls and a floor. Their total outputs can thus be a mixture of negatives and positives.

This brings us to a second major force, that of total environmental loading. As economic development progresses, the level of human activity on the landscape increases exponentially. House lots, roads, shopping malls and even golf courses, almost without exception, increase materials (chemical) loading on the environment and reduce the quality and quantity of ecosystem services provided. These areas, for instance are designed for surface water runoff rather that for infiltration and groundwater recharge, as good agriculture does well. Groundwater recharge is a much higher value ecosystem service. All of this "development" means that agriculture's share of tolerable environmental loading is decreasing, while the demand for its ecosystems services is increasing. Our global economic marketplace must eventually mature to the point (augmented by regulation and other policy) where it truly values the services and presently "external" costs of our development and our food system. Until that maturity occurs, more public sector intervention is required.

The final point I would mention is that of complex social community and peripheral support networks needed for land use (agricultural) sustainability. Production capital is increasingly mobile, and will continuously move in pursuit of even minor increases in profit margin. Arable farmland is not mobile, nor are the communities which bring production stability to it.

In summary, an unfettered global marketplace, posing under the name of "free" trade, is leading us toward several dimensions of unstable and eventually ruinous land use, unsupported by the long-term self-interest of local communities in their production stability. An unfettered "free" trade global marketplace for food, coupled with uncontrolled economic development exerts huge checks and balances of the US or European systems, many developing countries such as Mexico, India, China and several African countries bear stark testimony to marketplace failure to provide ecosystem balance and services as well as "cheap" food.

As we enter the 21st century we must ask ourselves if we have the courage to choose pathways to productivity and well-being which avoid the simplistic notions of "free" goods and of "free" trade, the notion of "something for nothing?" Our food systems are both the "miner's canary" of danger as well as being the most environmentally and socially sensitive segment of our economy. How can we structure our food systems toward an appropriate level of local food diversity and supply? How can we stabilize them both socially and environmentally? Many of the changes we are making in landscape use and in the structure of our food system are essentially irreversible. Are we awake? Or doesn't anyone really give a damn?

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