SALT of the EARTH

Salt problems are particularly insidious. They do not come charging at you with trumpets blowing and battle flags flying, a sight to set stirring the hearts of activists in any century. Rather, they slip in almost unnoticed. . . Time is of no concern, for they are supremely confident of their ultimate victory. History is on their side, as are the laws of physics, and chemistry, and biology. They have quietly destroyed, without fuss or fanfare, more civilizations than all of the mighty armies of the world.

—Warren A. Hall, July 1973, then acting director of the Office of Water Resources Research, U.S. Department of the Interior

First of two articles

By JANET RALOFF

Kay Muldoon/World Bank-IDA

Farmer opens irrigation ditch in Pakistan, where 250 acres are lost to salt daily.

Irrigated agriculture was born more than 6,000 years ago in the Mesopotamian floodplain of the Tigris and Euphrates rivers. Part of what would later be known as the Fertile Crescent, this region once fed a population of between 17 million and 25 million people and gained renown as a net food exporter. So much of the region is now desert, however, that even though its population is only about half what it once was, it must import large quantities of food. What transformed this fertile delta into desert? There are, of course, a number of reasons, but many experts believe that salt should head the list.

The problem of soil salinity is as old as irrigation. Although it is not widely appreciated outside those regions that are severely affected, low visibility in no way diminishes its stranglehold on arid farming. Today, as in ancient Mesopotamia, many of the world's most productive farmlands are in jeopardy of "salting out."

Salt is crippling agricultural production not only in North Africa and the Middle East but also in North America, South America, Australia and Asia — including China and the Soviet Union. Determining the exact acreage involved is difficult, but some of the estimates are alarmingly high. For example, Georg Borgstrom, retired professor of food science and human nutrition from Michigan State University in East Lansing, told SCIENCE NEWS that, based on studies published over the last few decades, "at least 50 percent, and presumably now close to 65 percent, of all irrigated land will be destroyed by salt before the end of the century."

"We're just reaping the results of not paying attention to the problem for the past 100 years," maintains Stephen Rawlins, a member of the staff setting priorities for the U.S. Department of Agriculture's (USDA's) Agricultural Research Service. "As long as the problem is 10 years or more away, we don't worry about it. But time is up now and salinity must be dealt with." Moreover, with most of the best land for irrigation already under the plow, Rawlins says, "we can no longer afford to farm our land till it salts out and then abandon it for some new tract." Helping to create a crisis, he believes, is the fact "that we're starting to come up against a food crunch in many of these older irrigated areas — like in Pakistan and India."

All water, even "fresh" rainwater, contains some dissolved salts. Rain may acquire some from pollutants in the air. River water and snowmelt accumulate some from the rock beds they erode. And soil contributes some to whatever water percolates through it. Though plants may find low levels of some salt constituents beneficial, salt concentrations upwards of 2,000 to

3,000 parts per million (ppm) are generally toxic. (Rainwater has on average 10 ppm salt, while seawater has 35,000.)

On croplands where rainfall is plentiful and drainage good, salt will be regularly flushed through the soil and out to the ocean via rivers and subterranean passageways. Where rainfall is low, salts may never flush out of the root zone. And where drainage is restricted or nonexistent, saline pockets of groundwater will develop over time. However, salt hazards frequently go unnoticed until farmers decide to transform arid zones into oases of productive croplands through irrigation.

That's exactly what happened in California's San Joaquin Valley, where large-scale irrigated agriculture began developing around 1870. Bordered by three mountain ranges and the delta of the Sacramento and San Joaquin rivers, it is one of the most important agricultural areas in the world. The 250-mile-long valley produces close to $5 billion worth of crops annually. In fact, three of its eight counties head the nation in farm marketings. But with rainfall averaging only 14 inches a year in the north and a mere 5 inches annually in southern and western stretches, high productivity is sustained only with irrigation.

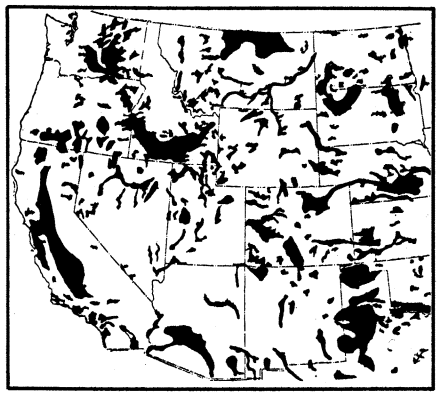
As a result of that irrigation, however, half a million of the region's 5 million irrigated acres are already seriously affected by salt, according to Gerald Horner, an agricultural economist with the USDA's Economic Research Service in Davis, Calif. Figures compiled for the State of California predict that within 15 years the affected acreage could double.

The region's rich soils built up over millions of years through the erosion of its surrounding mountains. Rock particles settled out in the order of their size, with the largest forming light, permeable soil in a perimeter about the valley floor. Rain and snowmelt carried the tiniest particles to the valley trough, eventually creating five layers of virtually impermeable clay. Today the most salt-affected regions lie atop that clay, some of which is only 12 to 40 feet below the surface. With no natural drainage, water entering the valley stays put until it either evaporates or is pumped out.

A 1979 analysis of the situation by the Interior Department's Bureau of Reclamation, the California Department of Water Resources and the State Water Resources Control Board noted that typical irrigation water there contains salt in concentrations of about 350 ppm; "but even this low concentration means that about 1 to 1.5 tons of salt are being applied to each irrigated acre annually. Since [water] evaporation from the soil and transpiration through plant tissues (collectively termed evapotranspiration) extract essentially pure water, nearly all the salt content of the applied water is added to the soil." Moreover, the report says, when two major new water projects "reach their expected ultimate deliveries into the valley of about 5 million acre-feet per year, the salt being imported to the valley [via irrigation water] will total about 2 million tons each year. This is enough to cover almost 1,800 acres with a layer of dry salt a foot deep."

In the beginning, salt will stunt a plant's growth. When levels get high enough the plant simply dies. In order to keep salts from building up in the plants' fragile root zone, excess irrigation water — more than the crops actually need for growth — must be applied periodically to wash, or leach, salts deeper into the soil profile. But with an impermeable clay layer under much of the San Joaquin Valley, this salty leachate will eventually build up to waterlog the root zone in toxic brine if drainage isn't provided.

For many farmers, however, installation



Hedlund/Salinity in Watercourses & Reservoirs, © 1984

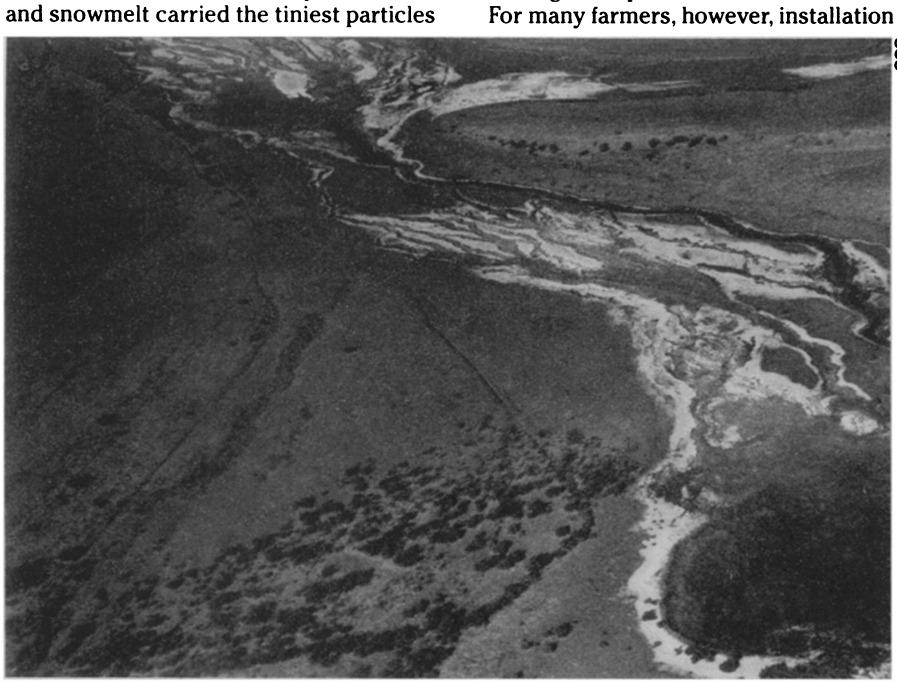
Dark areas on this map show salt-affected cropland soils in the western United States, illustrating the magnitude of salinity problems there.

of drains won't end their problems. Typical annual drainage volumes in the valley have been running about half an acre-foot — or 163,000 gallons — per acre irrigated, according to Horner. That means that even a small farmer will generate millions of gallons of wastewater — drainage so salty that it frequently defies reuse for any other purpose. The seemingly intractable and growing dilemma is what to do with it.

Explains Horner, "We can't use the natural water sources because half the valley is a closed system [having no natural outlet] and the other half has been closed because of water-quality constraints. So what we're doing now is building evaporation ponds." Horner estimates that affected landowners—primarily those farming the valley's trough — must use anywhere from 5 to 10 percent of their acreage for these evaporative ponds.

And what isn't immediately obvious, he points out, is that the cost of retiring land to concentrate saline drainage goes beyond the mere land removed from production. Not only must the ponds be lined to keep the saline leachate from escaping, but landowners must also build a conduit network of subsurface drains and a pumping system to transport that drainage water into the ponds. "So when your land has a drainage/salinity problem, your fixed costs might double," Horner says. Given the grim economic picture facing most farmers as it is, he says, these ponds will probably be enough to make those who had marginal operations "go under."

In addition, new research indicates that the ponds may create a hazard to wildlife. A report issued in August by the Bureau of Reclamation notes that toxic levels of selenium — a natural trace mineral in soil —have built up in some San Joaquin Valley drainage water being stored in its Kesterson Reservoir. The heavy-metal pollution was signaled by birth defects and high rates of fetal mortality among local waterfowl.



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Here in Colorado, white areas depict salt picked up by subsurface flow of irrigation drainage over shale deposits.

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Tim McCabe/SCS

Highly saline irrigation water has seriously damaged crops in California's Imperial Valley.

Imperial Valley, another of California's prime agricultural regions, is also suffering serious salt problems. According to Myron Holburt, former chief engineer with the Colorado River Board of California in Los Angeles, "In Imperial Valley, farmers have installed over 28,000 miles of drainpipes, at a cost of over $72 million," in an attempt to manage the salt being deposited onto their fields by irrigation water.

Holburt says the Colorado River, a primary source of water for Imperial Valley farmers, is classified as highly saline for irrigation purposes. If irrigators aren't careful in managing its use, he warns, they might be forced to switch to more salt-tolerant crops, which as a rule are less profitable.

In comparison with the San Joaquin, Imperial is a small valley. Yet drainage water coming off fields in this closed basin "amounts to somewhere in excess of 1 million acre-feet a year," explains James Rhoades, research leader in soil and water chemistry at the U.S. Salinity Laboratory in Riverside, Calif. "For sake of perspective," he adds, "this is about the water supply of the nation of Israel — not a small volume." But unlike the San Joaquin farmers, Imperial Valley growers at least have somewhere to send their saline drainage for permanent disposal — the man-made Salton Sea.

Salinity problems similar to California's are occurring in areas throughout the western United States (see map). A graphic portrait of salt's international dimensions is conveyed by a recent 97-page study out of the Washington office of Ear:hscan, an information agency of the Lonc.on-based International Institute for Environment and Development.

It found, for example, that:

- roughly half the irrigated land in Syria's Euphrates Valley has become saline to the point where crop losses now total an estimated $300 million annually
- between one-quarter and one-half of all irrigated lands in South America are affected by salinization "and the problem is increasing as fast as new lands are being brought under irrigation"
- in India, 35 percent of all irrigated land is seriously saline
- and in Pakistan, where 80 percent of all croplands are irrigated, a third of the irrigated total — or 12.8 million acres — is already experiencing severe salt problems and another 16 percent is threatened with salinization by high water tables. In fact, the report says, another "250 acres go out of production every day [in Pakistan] because of salinity."

Citing figures by the United Nations Food and Agricultural Organization (FAO), Earthscan reports that today "about 120 million hectares (300 million acres)—half the world's irrigated land—suffer from reduction of crop yields due to salinization."

Not everyone accepts that number. Among those who differ is Harold Dregne, a senior land resources adviser to the Agency for International Development in Washington, D.C., and a renowned scholar on desertification (of which salinity is a primary cause). Dregne has compiled his own statistics, and they indicate that such a figure represents merely the area "continually threatened with waterlogging and salinization" to the point where desertification could result. But Dregne also admits that arguing over the statistics is rather pointless because even the best figures "are very imprecise — educated guesses really."

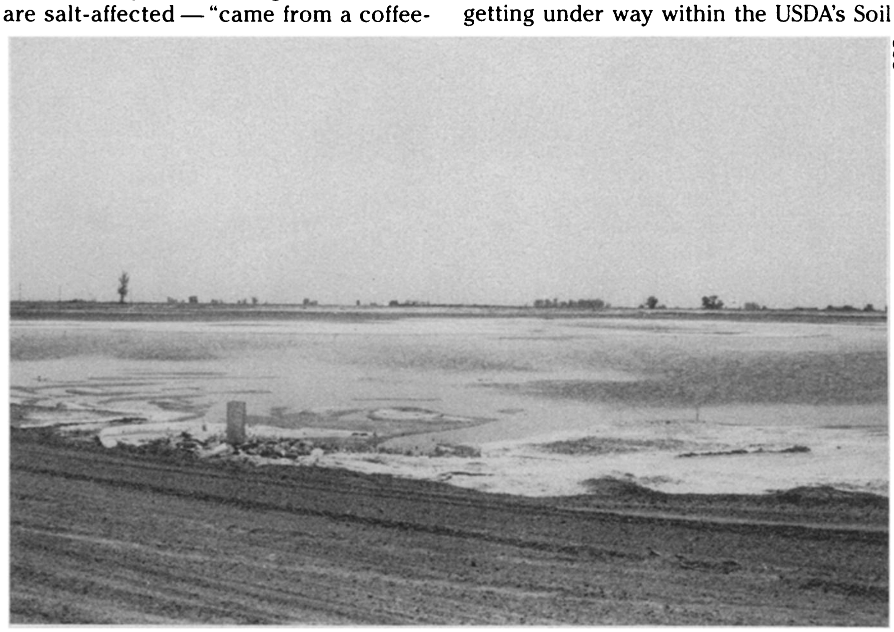
On that, Jan van Schilfgaarde agrees. Van Schilfgaarde, who until September directed the U.S. Salinity Laboratory, notes that the more widely quoted statistic—that 30 percent of irrigated arid lands are salt-affected — "came from a coffee-hour discussion here at the lab 25 years ago." Though to this day everybody quotes it, he acknowledges, "we have no statistics to back it up."

Rhoades, now acting director for the salinity lab, points to one of the primary reasons the problem has thus far defied quantifying. "One has to take many soil samples to get something representative of an area — not only across the landscape, but also with depth." What's more, he notes, "a soil's salinity changes with time: as the water table goes up and down, as a farmer changes from one crop to the next, even as he changes [irrigation or tillage] practices. So there is a tremendous sampling requirement." And at perhaps $25 per analyzed sample, he says, "you can see that accurate sampling has been essentially prohibitive."

Rhoades has been working on new technologies to make sampling quicker, easier and less costly. But the fruits of his labors are still so new that they have not yet been used to do any serious salinity mapping on a large scale.

Further complicating quantification of salinity is the fact that "many farmers don't even recognize they have a problem until it gets so grossly bad that it's obvious," explains George Stem, chairman of the Soil Conservation Service's Salinity Assessment Leadership Team (SALT). Stem says, "You could lose 5, 10 or even 15 percent of your productivity while you're developing a salinity problem" — a loss that is within the normal variation that could occur from year to year just due to changes in temperatures, rainfall or farm management practices. In fact, unlike most blights "there aren't any real symptoms" to low levels of soil salinity, notes Rawlins of the Agricultural Research Service. "The crops just grow worse — not quite as big."

But a national soil salinity assessment — the first in the United States — is just getting under way within the USDA's Soil



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In San Joaquin Valley, costly evaporation ponds can exceed 50 acres in size. This one covers more than 20 acres.

Conservation Service. Stem is hoping that when its results start pouring in — probably some time just after the first of the year — they will convince policymakers in Washington that controlling salinity should be a national priority.

It's ironic, Stem says, that although controlling salinity is essential to conserving soil quality, the Soil Conservation Service has given salinity "very little recognition in terms of our *national* problems." He attributes that in part to the perception that salinity is a regional problem affecting only the West. He suggests that another reason for salinity's low profile within the Soil Conservation Service's action plans is the agency's focus on controlling erosion. Stem maintains that while erosion is unquestionably a serious problem that shows no regional preferences, in many ways it can also be less devastating than salt: "Even if you have erosion for 50 years," he says, "you still generally can produce something on your land. But you let the salinity problem get bad, and boom — your productivity is gone."

Stem also believes that, "without question," the salt problem will only be getting bigger. And to illustrate his point he notes that serious salinity problems are beginning to develop for the first time in the eastern part of the United States. By overdrawing groundwater, he says, several Atlantic and Gulf Coast states are beginning to get saltwater intrusion into what were formerly freshwater aquifers — sources of water for both drinking and irrigation.

So what are the prospects for the future? "In theory, soil salinity is a reversible problem anywhere," according to Dregne. Except where the soil is heavy clay, he says, "you can cleanse any problem if you have enough low-salt water to flush through the soil and as long as you have drainage" to carry away the salty wastes. The rub is that "it gets to be expensive."

In Egypt's Nile Delta Valley, for example, where the Aswan dam has eliminated the periodic flooding that used to wash salts out of the upper topsoil, a drainage system is now being installed at an estimated cost of $1 billion, Dregne says. "And that will take care of only a part of a small valley." The cost of contending with the San Joaquin Valley's most serious crisis — no place to permanently dispose of highly saline drainage — could also prove to be massively expensive. One proposal that has been suggested — to pipeline drainage over the mountains for ocean disposal — could cost $44.7 million annually. A less expensive option, to dispose of it in the ocean via San Francisco Bay, has met with continuing vehement political opposition on environmental grounds.

In fact, most analysts now consider politics and economics to be the leading obstacles to controlling salinity. Take the "equity issue," Stem says. The Colorado River is the leading source of irrigation water for the Southwest. At its headwaters salt concentrations are only about 50 ppm. By the time they reach California, however, they have increased 20-fold. Even though upstream users may have contributed substantially to the downstream salt loading, they resent being asked to pay for cleaning up California's water, Stem says. Similarly, California farmers resent having to pay the costs of managing salts washed downriver to them. Economist Horner believes the attitude is building, at least in California, that if a farmer can hold out long enough from taking corrective action, eventually the federal government will step in with subsidies. He says many farmers seem to be banking on the assumption that Congress won't let the nation's most productive farm districts salt out.

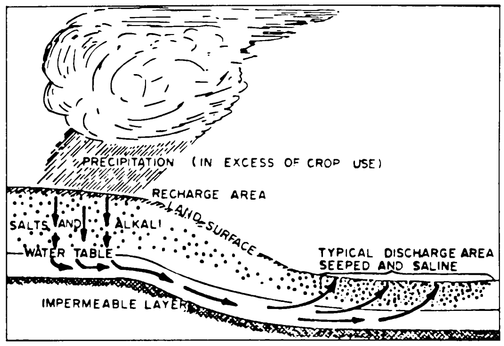
Dregne has observed that in many other regions, especially developing countries, irrigation farmers frequently cannot afford the technology to manage salt better, or they lack the education and guidance to put that technology to effective use.

These socioeconomic and political problems tend to be far less tractable than the technological ones. And that's why few experts expect to see the salt problem effectively harnessed in their lifetime. □

Next: How technology can help

Saline seeps

The one major salt problem in agriculture not associated with irrigation is the saline seep. "In the northern Great Plains of the United States alone, an estimated 3.5 million hectares [8.6 million acres] of land may be affected by saline seeps," according to the Council on Environmental Quality's 1984 annual report. As with the more common form of soil salinity, no reliable estimates exist for the magnitude of this problem in croplands worldwide, although it is known to be a serious problem in Canada's prairie provinces, India, Iran, Turkey and Australia. In fact, notes Stephen Rawlins of the USDA's Agricultural Research Service (ARS), seeps are "a devastating problem" in western Australia ("it's salted up all their rivers"), in large part because "their continent is much older and has accumulated far more salt that can be flushed out."



In the United States, these seeps tend to develop in soils formed by glacial till that are naturally rich in magnesium, sodium and calcium salts. Underneath the soil lie impermeable strata. Over millennia, rainwater adds to the soil's natural salt loading. However, because this climate is arid and the native vegetation has the capacity to make the most of what little rainfall there is, the salt never was flushed out of the soil before farm crops were introduced.

Then came farming. Because farm crops are generally not as efficient at using water as the native plants, rainwater finally began trickling down the soil profile, collecting salt along the way. Since rainfall in these arid climes won't support crops on a regular annual basis, a cropping cycle has evolved in which fields are regularly denuded and fallowed every other year or so, to allow more water to collect. As farmers have lately been discovering, after enough of these cycles the briny water table rises enough to allow the water — often as salty as the ocean — to seep to the surface in regions via capillary action (see diagram).

Luckily, research has found a way to cope. A regimen developed by ARS soil scientists Paul Brown in Bozeman, Mont., and Ardell Halvorson in Akron, Colo., involves seeding alfalfa — an extremely thirsty and deep-rooted perennial — in the water recharge area (where the water first collects upslope of the eventual seep). In some less serious cases where the impermeable strata are close to the surface and farmers have no use for alfalfa, grasses may be substituted. The researchers also recommend abandoning regular fallowing in favor of planting a crop whenever the soil moisture level will — with the addition of predicted crop-season rainfall — provide sufficient moisture.

A seep-reclamation report in the February issue of USDA's Agricultural Research describes one Montana farm that had developed a water table 1 foot below the soil in the seep zone (water tables within 5 or 6 feet of the surface will usually permit seepage to the surface by capillary action) and 19 feet below ground in the recharge area. After six years of planting alfalfa, however, the water table dropped 9 feet. The following year the farmer was able to begin planting wheat, barley or other crops in the former seep. According to the ARS researchers, the hardest part of reclamation often is identifying the recharge area where water collection occurs.

—J. Raloff