Summer 1990

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Historical perspectives on sustainable development.

Ponting, C.

Environment 32(9):4-9, 31-33. 1990

Reviewer's note: This article is derived from the author's book: Ponting, C. 1991. A Green History of the World. Sinclair Stevenson, Ltd.., London.

Solving today's environmental problems takes on a new sense of urgency when considered in light of the decline of natural resources of past eras. Historical texts fail to acknowledge the direct relationship which often existed between the rise and fall of civilizations, and poor soil and water management. This article investigates that relationship and poses questions about the future of our own civilization.

Before the development of agriculture, people lived in small, migratory groups. This period was one of great ecological stability; nearly all parts of the globe were inhabitable and people had enough food and water to survive. The development of agriculture about 10,000 years ago enabled people to live in concentrated population centers. Expanding populations led to increased demand for resources and ultimately to massive disruption of natural ecosystems. The article examines how three societies exploited their natural resources, attempted to deal with their ecological problems, and ultimately declined as a result of the deterioration of the resource base.

Mesopotamia. A classic example of an agricultural system that was not sustainable is seen in the southern Mesopotamian region (Sumer) during the third and second millennia B.C. Because of lack of rain during the growing season, water storage and irrigation were necessary. Rapid evaporation of water from soils, caused by high temperatures, and high water tables led to the buildup of salts on the soil surface. Allowing the land to lie fallow would have lowered water tables, however limited land availability and rising population only increased the pressure to intensify food production.

In about 3500 B.C., wheat and barley were grown in roughly equal amounts. Gradually less and less wheat could be grown due to high salinity, and by 1700 B.C., only the salt-tolerant barley could be grown throughout the entire region. Crop yields also drastically declined during this period and entire fields turned white with salts and became unproductive. The most interesting feature noted about this time period involves the political history of the region. Military conquests of the region, outlined in the article, closely followed the steady decline of the agriculture base. Ultimately, Mesopotamian society shifted permanently to the north, while Sumer became underpopulated and impoverished.

The Mediterranean Region. Environmental degradation and the shift in the plant species of the region occurred as a result of "relentless pressure of long-term human settlement and growing population." The natural vegetation of the Mediterranean basin was a mixed evergreen and deciduous forest, but forests have been cleared steadily for fuel and for use in agriculture and construction. For example, about 90 percent of the original forests along the eastern Mediterranean have been removed. Of notable stature and importance were the famed cedars of Lebanon, of which only four small groves remain.

All other areas of the Mediterranean have suffered a similar environmental decline as well. In Greece, over-grazing caused severe soil erosion, mostly during the seventh century B.C. This led to the widespread planting of olives, which were the only tree that had roots strong enough to penetrate the limestone rock underlying the badly eroded land. Rapid deforestation in Italy resulted in soil erosion so severe that numerous ports in estuaries became silted up from the eroded hillside soils. The ecology of North African provinces declined much more slowly, but intensified after the fall of Rome. Tribes brought in large flocks of grazing animals that denuded the remaining vegetation and led to increasing desertification.

The Maya. The Mayan civilization of Central America consisted of large and complex population centers which date back to 2500 B.C. Recent archaeological work indicates that some cities had populations of 30,000 to 50,000, and the entire Mayan lowland jungle may have had as many as 5 million people. Pyramids were built in these cities between 600 and 800 A.D., after which population levels fell abruptly, and the cities became covered by the encroaching jungle.

Many historians formerly believed that the Mayans obtained their food primarily by using swidden agriculture. Swidden agriculture involves temporarily clearing and burning a patch of jungle, growing maize and beans for a couple of years, and then abandoning the plot for 20 or more years until the jungle grows back. This form of agriculture was clearly incapable of supporting such a large population.

Recent investigations have found an intensive agricultural system, which included extensive terracing on highly erodible hillsides, as well as raised fields constructed in swampy areas. Increasing population likely pushed agriculture largely onto the most marginal soils, and forests were cleared for crop production, fuel, and construction. Eroded hillsides probably became unarable, and silt carried by rivers would have seriously damaged the flatland raised fields. The continuous warfare now known to have occurred among Mayan peoples likely intensified because of reduced food production and declining natural resources. The result was a rapid population decline and a return to far less intensive methods of food production.

The author concludes by posing two increasingly important questions: "Are contemporary societies any better than ancient ones at controlling the drive toward ever greater use of resources and heavier pressure on the environment? Is humanity too confident about its ability to avoid ecological disaster?" Finally, "Given the 2-million-year history of humans on Earth, it is still an open question whether the 10,000-year-old development of agriculture and settled societies and the more recent dependence on nonrenewable fossil fuels constitute an ecologically sustainable strategy."

Contributed by Chuck Ingels

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Summer, 1990 (v2n4)

The impacts of farmland conversion California.

Jones & Stokes Associates, Inc.

California Department of Conservation, Office of Land Conservation. 1991

Reviewer's note: This 97-page study was commissioned by the Office of Land Conservation of the California Department of Conservation in response to the lack of available information on the socioeconomic and environmental impacts of farmland conversion. Prepared by Jones & Stokes Associates, Inc., an independent, Sacramento-based consulting firm, the report makes significant progress in identifying the rate and extent of farmland conversion in critical agricultural regions, and documenting the resulting impacts. While not a definitive study, the report is sure to serve as an invaluable springboard for future research. It may also prompt reforms that strengthen the way state officials assess the environmental impacts of farmland conversions.

Methodology

The report is based on published data and interviews with more than 70 individuals directly concerned with farmland conversion and related issues. The interviewees represented a range of interests and backgrounds, and included officials from county agricultural offices, planning departments, and UC Cooperative Extension; also interviewed were environmental officials, farmers, farm labor contractors, and soil conservationists.

The heart of the document consists of two case studies of farmland conversion, one in Ventura County, and the other in the Northern San Joaquin Valley (San Joaquin and Stanislaus counties). In each case two types of conversion are considered: cropland to urban uses ("Type A" conversions) and wildlands to croplands ("Type B" conversions). The study examined conversion patterns over the past two decades, with a focus on those that took place between 1984 and 1988.

A special concern of the study was to evaluate the adequacy of the impact analysis of farmland conversions that has taken place under the California Environmental Quality Act (CEQA), and to recommend amendments to improve the environmental impact reports (EIRs) for proposed conversions covered by the Act. A total of 26 past EIR's that involved farmland conversions of over 100 acres near urban areas were reviewed to determine their rigor and comprehensiveness.

Results

Acreage loss. Not surprisingly, the study finds that prime farmland is being lost to urban expansion near existing cities. In the northern San Joaquin Valley, alfalfa and field crops lost the most acreage Table 1), while in Ventura County, vegetables, citrus and field crops experienced the heaviest losses (Table 2). In both Stanislaus and Ventura Counties, Type B conversions of wildlands to croplands were roughly equal in area to Type A conversions. Type A conversions were dominated by new avocado orchards on hilly terrain (Ventura County) and almond orchards (San Joaquin and Stanislaus Counties). In San Joaquin County, little new cropland has been established since 1976.

The report echoes the alarm heard elsewhere about the diminishing supply of prime farmland: "If Type A conversion trends occurring between 1974 and 1986 continued through the year 2010, farmland losses in the Central Valley would exceed 300,000 acres, or over 4 percent of the state's stock of important farmlands. Projected over one century, urbanization in the Central Valley alone would claim one-fourth of the state's important farmlands."

Table 1. Farmland Conversions in San Joaquin and Stanislaus Counties (Acres).

Conversion Type	San Joaquin (1976-1988)	Stanislaus (1977-1988)
Cropland to urban conversions (Type A)		
Preconversion crop type		
Vines	1,430	1,080
Orchards	1,200	0
Irrigated pasture	1,570	30
Alfalfa & irrigated filed crops	5,550	6,320
Truck crops	740	4,530
Total	10,490	11,960
Wildland to cropland conversions (Type B)		
Postconversion crop type		
Almonds	60	10,290
Walnuts	40	460
Vines	190	0
Field and truck crops	420	2,460
Other	0	470
Total	710	13,680

Sources: California Department of Water Resources 1976, 1977, 1988.

Table 2. Farmland Conversions in Ventura County (1969-1988)

Conversion Type	Acres
Cropland to urban conversions	
Preconversion crop type	

Citrus	5,150
Deciduous tree crops	430
Irrigated pasture	220
Irrigated field crops	1,970
Truck crops	5,990
Total	14,580
Wildland to cropland conversions	
Postconversion crop type	
Avocados	9,800
Lemons	1,950
Truck & irrigated field crops	760
Other	610
Total	13,120

Sources: California Department of Water Resources 1969, 1988.

Impacts. The impacts of urban encroachment are examined from the perspective of both urban residents and farmers. For urban residents in these newly developed areas, nuisances and health risks such as pesticide exposure, dust, noise and odor are the most common complaints. For farmers, urban encroachment adversely affects the efficiency of remaining farming operations due to "increased air pollution, livestock predation by pets, crop diseases resulting from inadequate care off-farm ornamental plants, restrictions on pesticide use and burning, and requirements to set aside on-farm buffer zones." At the same time, production costs increase due to rising land values, water scarcity, theft and vandalism of farm equipment, crop pilferage, road congestion, and personal injury liability resulting from trespassing on farms. By reducing the profitability of remaining farming operations, urban encroachment tends to take on a spiraling effect, encouraging further losses of farms to urban development.

In terms of socioeconomic impacts, the report finds conversions to have little effect on the viability of the regional agricultural sectors. The most critical impact is on housing prices, which have risen as growth occurs. The report concludes that "farmland conversion appears to be correlated with worsening housing conditions for farm workers and other low-income segments of the population." Currently, most California farm workers who do not live in government-operated labor camps live in substandard housing.

Both Type A and Type B conversions are associated with negative environmental impacts such as the loss of wildlife habitat. Type B conversions can increase groundwater scarcity and sometimes increase groundwater contamination, while Type A conversions are expected to have a beneficial impact on water quality due to reduced pesticide use and replacement of septic systems with municipal wastewater treatment facilities. Increased air pollution due to vehicle emissions (due to Type A conversion) and atmospheric dust (due to Type B conversion) are also found. In fact, "acid fog" is now becoming a recognized problem in the San Joaquin Valley and ozone pollution is responsible for significant reductions in yield. For example, one study cited in the report found a 34 percent reduction in grape yield due to ozone pollution.

The report finds existing CEQA EIR's inadequate, because they have tended to focus too narrowly on loss of prime soils without considering the related issues. It recommends a broader focus along the lines used in this study and improved guidelines to assist lead agencies and EIR preparers.

Reviewer Comments

The report paints a predominantly negative picture of how farmland conversion impacts the sustainability of California agriculture. Aside from the environmental impacts, the most important issue related to sustainability identified in this report is the influence of rising land values. Escalating values create barriers to entering farmers, and pressure existing farmers to change to high-value crops to make mortgage or rental payments. High land values also encourage farmers to view their holdings in light of their short-term development potential, as opposed to making long-term investments that improve the holding's agricultural value. In general, these pressures discourage farmers from adopting sustainable practices and a long-term perspective on the value of their land.

On the other hand, the increased proximity of urban residents to farms is creating pressure to curb pesticide usage, burning, etc. This pressure provides a tangible incentive for farmers to consider a range of alternative practices. A key issue that will determine whether agriculture can be preserved on prime soils is whether the transition to these practices can be made economically. Policymakers can help by increasing support for research on sustainable practices and providing economic aid to help farmers during the transition. More broadly, the Office of Land Conservation report emphasizes the need for growth management policies that protect prime farmland from urban encroachment. Finally, the report underscores once again the need for policies that address the glaring need for adequate low-income housing for California's farm workers.

References

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Contributed by Dave Campbell

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Hunger in the Heartland

California Rural Legal Assistance Foundation. 1991

Reviewer's note: This study is part of a national effort by the Washington, D.C. -based Food Research and Action Center to document hunger in various regions of the country. The California Rural Legal Assistance Foundation (CRLA) carried out the California component of the Community Childhood Hunger Identification Project (CCHIP) in California's Central Valley. It was one of nine CCHiP surveys conducted in different states across the country. CRLA operates both statewide and within communities to address the needs of California's low-income rural residents in the areas of health and nutrition, housing, education, economic development, labor and immigration..

In the midst of some of the richest farm areas in the world in California's Central Valley, low-income families - many of them farmworker families - struggle to survive. Hunger and poverty stand in stark contrast to the Valley's economic recovery. Even as farmworkers work to grow and harvest much of the country's fruits and vegetables, returning billions of dollars to California's economy, they and their families often do not have enough to eat. These are some of the findings of *Hunger in the Heartland,* the California Rural Legal Assistance Foundation's study of poverty and hunger among children of Fresno, Kings, Stanislaus and Tulare counties.

Methodology

Project researchers used a questionnaire developed and field-tested by the Connecticut Association for Human Services. This questionnaire was designed to estimate the prevalence of hunger, defined as "the mental and physical condition that comes from not eating enough food, due to insufficient economic, family or community resources." The questionnaire also explored some of the socioeconomic and demographic factors associated with hunger in some low-income families. The CCHIP surveyed a sample of low-income families in the four-county area. This sample was assumed to be representative of all low-income families at or below 185% of the federal poverty level with at least one child under 12. These low-income families represent 13 percent of all households in the four-county area.

The CCHIP staff randomly selected 12 census tracts, covering 13 communities for the survey area. Families in each census tract with incomes below 185 percent of the 1989 poverty level were then randomly chosen for the study. In total, trained community residents interviewed 335 eligible families with at least one child under age 12. There were more than 100 questions, which focused on household food security and experience of hunger, family size and structure, shopping and eating habits, participation in food assistance programs, employment and family finances, and children's health and health care.

Results

Responses to the survey document a clear pattern of hunger and related nutritional and health problems among the children of low-income families in California's Central Valley. More than one- third of the study families face severe hunger, i.e. they encounter serious problems getting enough food and they experience regular food shortages (Figure 1). These families answered "yes" to five or more of the eight survey questions that dealt with hunger. Ninety-seven percent of hungry families run out of money for food an average of seven days per month. As many as 65,900 school-age children in the four-county area are hungry.

In addition to those families facing severe hunger, another 32 percent of the study families encounter periodic problems obtaining enough food (Figure 1). They answered "yes" to at least one of the questions that dealt with hunger. In total, over two-thirds of families in the study reported at least one instance in the last year when they did not have enough food to eat.

Hungry children in the CCHIP sample experience twice as many specific health problems as children whose families are not hungry. These problems include weight loss, fatigue, irritability and inability to concentrate. Despite these problems, the study children are not receiving even minimal health care. Twenty-three percent of the children have no medical coverage at all. An additional 18 percent are not covered by MediCal, although they do pay for some other health insurance. In total, 41 percent do not participate in the state MediCal program despite the fact that all children in families below 185 percent of poverty are eligible.

To cope with inadequate food, the hungry families surveyed have various strategies: 98 percent buy less expensive food, 82 percent get money from family and friends, 46 percent get food from friends and relatives and 46 percent use commodities from the federal government through local food banks and pantries (Figure 2).

What Contributes to Hunger?

The CCHIP study found that housing costs contribute to hunger. The average CCHIP household spends 44 percent of its income on shelter and 33 percent of hungry families spend more than half of their total income on shelter. To avoid homelessness, families pay housing costs and have little money left for food.

Another factor contributing to hunger is severe unemployment. Unemployment in the four counties studied (11.3-12.4 percent) is over twice as high as the statewide average (5.3 percent). Weather conditions, seasonality of agricultural work, plant closures and mechanization contribute to joblessness in the Central Valley, according to the study.

Although unemployment is higher than average for the state, the majority (53 percent) of CCHIP households have at least one member who works. Most of the employed respondents are farmworkers (51 percent). Although having a job helps, the average contributing adult in CCHIP households cannot find steady work (at least 10 days/month) for four months/year. Barriers to full-time work among respondents or contributing adults include: wanting to stay home with children, lack of child care, inability to find a job, language barriers, and lack of training and education.

Inadequacy of the Food Safety Net

Federally-funded food assistance programs are woefully inadequate and private sector food programs do not bridge the gap to prevent hunger, according to the study. The CCHIP survey found very low rates of participation in most food programs due mainly to the fact that families do not have access to them. The study suggests that improved funding, outreach, implementation and benefit levels would go far to prevent hunger in the Central Valley and other rural areas.

The CCHIP survey found that the Food Stamp Program is badly underutilized by low-income families with children in the Central Valley. Only 48 percent of the total sample participate compared to 58 percent in the Michigan CCHIP, 61 percent in the Minnesota CCHIP and 69 percent in the Connecticut CCHIP. Of those who have not applied for food stamps, 67 percent do not think their household is eligible. Of these, 74 percent probably *are* eligible. Of those families receiving food stamps, 39 percent are still hungry. One reason is that food stamp allotments are inadequate to cover food needs. In fact, families could only eat an average of two weeks per month using food stamps.

Participation in the Women, Infant and Children Supplemental Food Program (WIC) is also low. Only 30 percent of CCHIP families deemed eligible are receiving WIC. Again, this figure is significantly less than the percentage of eligible persons served by WIC in other CCHIP study states (38 - 77 percent). The majority of study participants (52 percent) do not receive WIC benefits because they think they are not eligible. Yet, WIC does not deny participation to undocumented families, and is mandated to target services to migrant farmworkers who are a significant portion of this CCHIP population.

Conclusions & Recommendations

The study concludes that enormous social costs - in terms of health, MediCal, education, welfare and youth guidance expenditures - may be on the horizon for California's low-income children unless adequate food and nutrition can be provided. "Making sure that all families have enough to eat is the first, most basic step in implementing any plan to fight poverty." Unless hunger is alleviated, improvements in housing, education and jobs will not make much of a difference, the study maintains. Long-term solutions must involve an improved standard of living through better wages, benefits, public assistance, housing, education and transportation. However, the report's recommendations focus on shorter-term solutions involving food and nutrition programs as a first and essential step. The study suggests improvements in five federal food and nutrition programs as follows:

- Improve outreach, benefits and lower barriers to access in the Food Stamp Program.

- Expand California WIC to serve all eligible women and children.
- Mandate provision of School Breakfast to California's neediest children.
- Triple participation in the Summer Food Program to prevent seasonal hunger.
- Expand and improve coordination of private sector emergency food programs.

Hunger in the Heartland concludes, "The choice is ours: hunger can either be alleviated and prevented, or allowed to fester. If we do not invest in prevention, we will pay a much higher price in the years ahead"

Contributed by Gail Feenstra

Summer, 1990 (v2n4)

Biological degradation of soil.

Sims, G.K.

Advances in Soil Science 11:289-330. 1990

This extensive review (197 references) concerns the role of soil microbiota in nutrient cycling, waste and residue decomposition, and detoxification of environmental pollutants. If these processes are disrupted, human health can ultimately be harmed. Not all topics addressed pertain directly to agriculture, but the overall treatment may help in understanding issues of soil health and regeneration.

The Cast of Characters

Soil microbial communities are typically diverse. In addition, the roles of the various species are inextricably interconnected, so that, in experiments, direct and indirect treatment effects may be indistinguishable. This article considers mainly the bacteria and fungi.

Soil bacteria are mostly saprophytes or parasites. Their single-celled structure gives them access to resources and refugia unavailable to larger organisms, but it may be a disadvantage in accessing nutrients that are contained in relatively large particles (e.g., plant residues) that may contain valuable carbon, but be deficient in other nutrients. Even motile bacterial types, however, can occur in colonies in the soil, and this habit may confer advantages such as improved nutrient mobilization and absorption, and protection from drying, toxins, or ultraviolet radiation.

Mycelial fungi and actinomycetes have filamentous (threadlike and branching) growth habits that may make them better suited as early exploiters of relatively large fragments of lignified plant residue, because they can transport various nutrients among zones of enrichment. The filamentous habit also enables exploration of large soil volumes, provides protection against being washed through the soil profile, and permits specialization of cells to fulfill various functions more efficiently.

Microbial Metabolism and Soil Processes

Microbial energetics (and all forms of metabolism) are driven by the Gibbs free-energy yield derived from the chemical adenosine 5'-triphosphate (ATP). ATP can be generated by fermentation or respiration. The latter requires terminal electron acceptors (e.g., nitrate, sulfate, carbon dioxide, ferric iron, or molecular hydrogen), and producs greater amounts of ATP per unit of substrate. Fermentation is less feasible in the presence of either highly oxidized or highly reduced substrates, and results in accumulation of toxic products (simple organic acids) that can eventually impede the process.

Oxygenases are enzymes involved in the breakdown of aromatic and aliphatic compounds (e.g., lignins, hydrocarbons, various pesticides), and the dehalogenation of xenobiotic compounds. These processes, important in nutrient cycling and in detoxification of soils, can only occur in the presence of oxygen. (Reviewer's note: dehalogenation by *oxygenases* can only occur in the presence of oxygen, but dehalogenation *per se* may be more rapid under anaerobic conditions.) The pH of the soil solution is another factor that governs enzymatic activity. Particular enzymes (even if membrane bound) are only active over a narrow pH range.

Microbially-Mediated Soil Processes

Carbon entering the soil from plant sources (e.g., as cellulose) usually leaves as carbon dioxide or methane. At first glance, impairment of soil carbon cycling would seem to require severe environmental insult, because many species of soil fungi and bacteria can degrade cellulose. Nonetheless, such impairment has been observed in the field.

Nitrogen cycling includes mineralization, immobilization, nitrification, denitrification, and nitrogen fixation. N-fixation and nitrification are most easily disrupted. Nitrifying bacteria (e.g., *Nitrosomonas* and *Nitrobacter)* are sensitive to acidity and require aerobic conditions. Waterlogged soils can become anoxic and may not support nitrification. Symbiotic nitrogen fixation is a delicate and complicated phenomenon. Nodulation of legumes could be impeded by some kinds of pollutant molecules.

Phosphorus cycling could conceivably be impeded by anything that interferes with mycorrhizal fungi. Cycles involving sulfur, iron, manganese and other elements depend to varying degrees on microorganisms. These processes are not discussed in detail in the article.

Indicators of Biological Degradation

Sims identifies four general approaches to measuring biological degradation.

Community diversity can be used to assess perturbation of soil biology. Bacteria and fungi can be evaluated by "viable count" methods, most involve plating on nutrient-rich agar. These methods are controversial, as are their alternatives. Biodiversity of soil microbial communities can be measured by various mathematical indices that emphasize richness (number of species), equitability (evenness of allocation of individuals among the various species), or combinations of these two. There is no clear indication that more diverse soil communities are more resistant to pertrbation.

Nutrient cycling can be indexed by measurement of soil enzymes, various components of the N cycle, cellulose or wood degradation, and of respiration.

Accumulation of pollutants. Toxins may accumulate if soil microbial life is degraded. The soil's ability to dechlorinate organic compounds can be impaired, especially in sulfate-rich anaerobic environments. Heavy application of animal wastes to low- pH soils can lead to buildup of ammonium and a concomitant reduced functioning of *Nitrobacter*. This effect can result in nitrite accumulation.

Redox status. Anaerobic conditions can arise as a result of compaction or waterlogging. Oxygen diffusion is only 1/10,000 as fast through water-filled soil pores as it is through air-filled pores. Production of large amounts of methane would indicate the strongly reducing conditions associated with anoxia.

Effects of Toxic Substances on Microorganisms

Generally speaking, organic compounds are readily degraded in warm climates, and less so in cold. Toxic metals, on the other hand, can remain in soils and cause long-term damage to soil microbial communities regardless of temperature. Sims discusses the effects of pesticides and organic and inorganic pollutants.

Pesticides. Pesticides can influence soil microbial activity, at times paradoxically. Application of paraquat led to buildup of fungi and bacteria, but reductions in CO_2 production, cellulose degradation, and nitrogenase activity. Sometimes selective destruction of predators and the resultant buildup of their microbial prey can occur. For example, glyphosate or diquat + paraquat application led to the buildup of *Gaeumannomyces graminis* var. *tritici,* the causal agent of take-all disease of wheat. Inoculation with untreated soil led to suppression of the pathogen in the treated soil, suggesting the possible role of microbial antagonists.

Nitrification and symbiotic nitrogen fixation are especially sensitive to disruption by pesticides, probably in part due to the small numbers of species involved in these processes. At normal application rates, Amitrole, 2,4-DB, and diallate can inhibit nitrification for at least 8 weeks, whereas atrazine, bromacil, picloram, and simazine can do so for shorter periods. Some degradation products of these substances may also be inhibitory. There are also examples of no effect and (paradoxically) even stimulation of nitrification for some of the pesticides mentioned above. For symbiotic nitrogen fixation, denitrification, and ammonification, there are also cases of inhibition, no effect, and stimulation, but no specifics are recounted. Soil respiration is relatively in-sensitive to pesticide application, but antimicrobials, e.g., fungicides, can suppress it. (Reviewer's note: soil respiration is frequently increased upon addition of pollutants because they kill sensitive species which are then digested by survivors.)

Toxic organic and inorganic pollutants. These compounds can result from chemical synthesis, coal mining, and petroleum processing. Organic pesticides show less dramatic effects on soil microbiology than do other classes of toxic organics, probably because the former are screened to avoid such effects.

Oil spills in cold regions cause long-term damage to soil microbiology, including adverse effects on carbon (e.g., cellulose degradation) and nitrogen cycling (especially nitrification and nitrogen fixation). Some alleviation and enhanced degradation of n-alkanes occurred through fertilization with urea and phosphate. Addition of oil-degrading bacteria showed little promise. Addition of retorted oil shale (that from which oil has been extracted) can reduce soil fungal growth and bacterial species diversity, which is also adversely affected by pyridine contained in the retort water. Revegetation lessened the effect of oil shale, apparently because bacteria are insulated in the rhizospheres of the range plants employed.

Contamination by heavy metals (e.g., Cd, Cu, Ni, Pb, Zn) can cause long-term suppression of carbon cycling, microbial biomass, nitrogen fixation, nitrification, dehydrogenase activity, and mycorrhizal incidence. Toxic metals can be abundant in some sewage sludges. Microbes can mobilize and increase the toxicity of cadmium, perhaps by producing water-soluble ligands or otherwise changing soil properties.

Effects of Mining Operations on Soil Biology

Acidification can occur when excavation of ores containing iron sulfides leads to oxidative production of sulfates. Discharge waters from mine spoils may have pH values of 1-2, and can cause severe problems off site. Waters draining from coal mines and associated spoils can be high in Zn, Cu, Ni, or Mn, all potentially toxic. Reclamation of strip-mined sites does not arrest such discharges immediately.

Effects of Land Management on Soil Biology

In addition to the effects of pesticides and other toxic materials, soil biology may also be affected through various land management practices, including forest management and crop production.

Forest management. Prescribed burning in forests can lead to increased pH and availability of Ca and Mg. On the other hand, hot fires can lead to loss of S, P, and B, and destruction of surface structure leading to lowered infiltration and increased runoff and erosion. Cool fires can lead to formation of hydrophobic surface layers that decrease infiltration and consequent soil moisture. On the other hand, fires can also inhibit certain fungi whose mycelia previously imparted a hydrophobic character to the soil surface. Under these conditions, infiltration can be increased. If fire darkens the soil surface and increases insolation by opening the forest canopy, soil temperatures can be increased. Effects of fire on soil microbiology are usually transitory, and mainly involve the surface strata. There can be increased nitrogen fixation following burns and either long-term increase or decrease in nitrification.

Clearcutting of hardwood deciduous or conifer forests leads to a reduction of litter inputs, increased microbial breakdown of litter, and a consequent reduction in forest-floor biomass, decreased shading, and increased soil temperature and pH. The latter two phenomena lead to increased nitrification, which can in turn lead to nitrate-rich runoff and pollution of nearby streams. In-creased release of nitrous oxide, a significant greenhouse gas, may also occur.

Cropping Practices. Studies on farming practices, including the long-term studies at Broadbalk Field, England, illustrate the constancy of some soil biological processes under continuous cropping and fertilization regimes. One plot received no nitrogen fertilizer, but P, K, Na, and Mg were added. Annual biological nitrogen fixation was estimated to be 40-60 kg N/ha, and soil N content remained between 0.107 percent and 0.105 percent. These values have remained virtually the same for over 100 years. Several studies of rice culture have yielded analogous results, and have also shown that the addition of N fertilizer arrests fixation by cyanobacteria in sediment and water, and by heterotrophic bacteria in the rhizosphere.

Microbial communities appear to be tolerant of normal farming practices, but are at best barely able to meet the nitrogen requirements of crops. Fallowing may lead to reduced microbial biomass, mainly through reduction of fungi. The addition of manures may raise carbon and nitrogen levels in soils without affecting numbers of bacteria, fungi, or protozoa. There is no clear evidence that

pesticides or fertilizers cause long-term degeneration of soil microbial diversity or biochemical potential.

Soil erosion is particularly deleterious to organic matter, which is less dense than other soil solids and at times less so than water itself. The clay fraction of soil, to which organic matter is often adsorbed, is particularly vulnerable to erosion. Vesicular-arbuscular mycorrhizae (VAM) can be adversely affected even by mild soil erosion. Survival of rhizobia in eroded soils may depend on their tolerances to pH of deeper soil horizons; soil pH, of course, is amenable to correction. Soil resistance to erosion is itself dictated in part by microbial activity, including the binding of water-stable aggregates through polysaccharidic exudates or VAM hyphae. Under tillage, carbohydrates associated with clay are relatively stable, but 27-43 percent of the total polysaccharides are contained in the light fraction, and these are subject to rapid loss. Carbohydrates as a class appear no more unstable than other classes of soil carbon taken together. Cultivation can lead to decreases in aggregate stability and increased susceptibility to soil erosion. In one study, soil under virgin prairie showed greater aggregate stability than soil cultivated for 14 years. Soil carbon associated with macroaggregates declined under cultivation. On the other hand, a study concerning a waterlogged meadow frequently fertilized with ammonium sulfate showed deteriorating soil structure while organic matter increased. This may have been due to acidification and the consequent adverse effects on bridges formed by divalent cations, which are important (along with polysaccharides and hyphae) in maintaining aggregate stability. The chronic waterlogging probably also interfered with organic matter cycling and aggregate formation.

Tillage, particularly of virgin lands, can lead to immediate and short-term increases in microbial biomass and metabolism. On the other hand, soil mesofauna may decline. Earthworms are often adversely affected, but not always. Incorporation of crop residues disperses microbial activity to a greater depth than is seen in reduced-tillage systems. The latter show aerobes, facultative anaerobes, and nitrifiers concentrated in the surface strata. Tillage also affects the composition of bacterial communities. Agricultural burning leads to loss of organic matter and the liberation of P and other cations. Soil pH increases, and there are often increases in soil microbes, N mineralization, and nitrification, although nitrifiers and N availability can be reduced. Burning is often accompanied by tillage, so effects are often compounded, or confounded, in practice.

Tillage of virgin lands causes slow decline in soil organic matter. In studies at Rothamsted Experiment Station, England, tillage of "prairie" led to a decline in soil C for 27 years, then a stabilization for the subsequent 100 years. The scientists postulated the existence of a persistent and a labile fraction of the total soil carbon. The former was believed to persist for 1,000 years or more, whereas the latter was believed to have a half-life of about 10-15 years. Soil N and C are both contained in organic matter; hence the close relationship observed between their concentrations. Tillage, in prompting the accelerated breakdown of soil organic matter, can liberate N in excess of that assimilable by the soil microbes. This excess is then lost through plant uptake, leaching, or volatilization.

Reduced-tillage (RT) typically supplies less N than does conventional tillage. Several explanatory hypotheses have been advanced:

- Under RT, denitrification potential of the microbial community is greater (some results have contradicted this idea; also, greater water content may be responsible rather than tillage per se);
- Concentration of residues at the surface under RT may lead to a greater immobilization of N relative to nitrification;
- Possible higher leaching losses under RT;
- Impairment of root metabolism due to impaired oxygen availability in soils under RT; and
- RT systems may require several years to reach equilibrium (as organic matter accumulates), at which point nitrification may be much greater than that observed earlier. Such a trend has been shown in a study of a 16-year old RT system.

(Reviewer's note: Sims makes no mention of increased volatilization of ammonia under RT, to which many researchers now ascribe the reduced N availability.)

Long-term changes under tillage appear related to gradual decline in soil organic matter, rather than to cultural practices per se. Tillage of virgin soils results in accelerated degradation of organic matter and consequent deterioration of soil structure with the increased threat of erosion. Erosion can lead to decreased microbial activity through further loss of organic matter and exposure of inhospitable deeper horizons. Under a given farming system, stabilization may occur with time, but reversal of the initial degradation is unlikely. Restoration of soil microbial communities may occur after cultivation ceases, but the recovery time is unknown.

Microorganisms as Pollutants

Microorganisms can themselves become pollutants; particularly hazardous are pathogens associated with livestock and waste-management operations. Dispersal of livestock (to avoid excessive concentration), application to lands only of treated sewage sludge, and the avoidance of below-ground septic systems in risky areas have all proven to be useful strategies in avoiding these problems.

Conclusions

Strip mining and metal contamination are much more serious perturbations to soil microbial communities than are the applications of pesticides. Communities in colder regions are much more prone to long-term disruption than those in warmer climates. Remediation of damage may require long periods of time, and damaged sites that return to relatively healthy status may not return to their pristine states. Remediation usually begins with ceasing the perturbation. long-term studies are required to test any proposed safe alternatives to current practices.

Acknowledgment: We thank Dr. Kate Scow, Land, Air & Water Resources Dept., UC Davis, for her critique of this summary.

Contributed by Robert Bugg

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Summer, 1990 (v2n4)

The effect of green manuring on the physical properties of temperate-area soils.

MacRae, R.J. and *G.R. Mehuys*

Advances in Soil Science, Volume 3:71-94. 1985

Reviewer's note: Green manures are crops which are turned into the soil in order to improve the growth of subsequent crops. This article reviews the non-nutrient benefits of green manures, i.e. their potential to improve soil organic matter levels, reduce soil compaction and soil erosion, and enhance crop yields. To narrow the scope of the analysis, the authors focused on literature relevant to field crop systems (mainly corn) in temperate regions. The information presented in the article partially explains the recent resurgence of interest in using green manures and cover crops, and also highlights the need for more and better research in this area. The review is a good introduction for those who want to find out more about the reasons for using green manures.

Historical Background

Earliest references to the use of green manures are from China, dating back to the 12th century B.C. Ancient records from Greece and southern Europe show that lupines and faba beans were favored in the Mediterranean region. A seminal work by Pieters (1927), suggests that the use of green manures occurred much later in northern Europe, and that colonists brought the practice with them to North America. The use of green manures on this continent reached a peak in the beginning of the 20th century, but has declined since the introduction of synthetic inorganic fertilizers. Historically, farmers used green manures as a way of improving soil fertility and increasing crop yields. Improvements in soil tilth that accrued through regular additions of organic matter may not have been as apparent.

Effect of Organic Matter on Soil Physical Properties

Research during this century has established that organic matter affects some soil physical properties more than others. This review focuses on aggregate distribution and stability, bulk density, moisture retention, and water movement.

Soil Aggregates. Organic matter plays more of a role in aggregate stability than in aggregate formation. It is, in fact, the primary stabilizing agent for aggregates in temperate-area soils. This stabilization process is accomplished mainly through the by-products of organic matter decomposition (microbial gums and mucilages).

Bulk Density. "With few exceptions, organic matter decreases the bulk density of soil." This effect can occur either directly by "diluting" the soil with a less dense material, or indirectly through greater aggregate stability. Indirect effects seem to be the most important and are not dependent on soil textural class.

Moisture Content and Availability. Soil organic matter has a variable effect on available water in soil. It is generally a positive relationship, but whether or not the effect is significant depends on other soil properties, notably texture. One experiment, for example, found organic matter to influence available water only in soils of medium to low clay content (13 to 20 percent); other researchers concluded that coarse silt, not organic carbon, was the primary factor determining available water in mineral soils. It is important to distinguish between *water retention* and *water availability*. Some sources of organic matter (like peat moss) have high water retention (i.e. they increase soil water holding capacity), but a portion of this water may be held so tightly that it is not available to plants. Increased soil aggregation can have a similar effect.

Water Movement. Organic matter has a strong, positive effect on infiltration of water into soils. This effect is due mainly to a decrease in bulk density, and improvements in aggregation and structure.

Effect of Green Manures on Soil Organic Matter

The maintenance or accumulation of organic matter in soils depends on a number of factors including: characteristics of the added material, soil and climatic factors as they affect microbial activity, and agricultural practices. All other factors being equal, it is generally accepted that low-nitrogen green manures (1.5 percent N or less) can be effective in improving soil organic matter levels. High-nitrogen materials such as legumes, on the other hand, cannot maintain organic matter levels because they decompose too rapidly. Varied reports from the literature suggest that each plant species should be considered on its own merits and in the context of the farming systems in which it will be used. Table 1 presents a sample of how diverse the literature is on this subject. Any interpretation of these varied results should also take into account soil type, soil nitrogen levels, native soil organic matter levels and microbial activity.

Study	Length of study (Years)	Soil Type	OM %	Initial Soil N %	Changes at end of study: OM . . . . Soil N	
Potting Studies						
Prince (1941)	40	Loam	3.9	0.19	Decrease	Decrease
De Haan (1977)	10	Sand	3.9	0.15	Increase	Increase
		Clay	3.0	0.22	Increase	Increase

Field Studies						
Poyser (1957)	25	Clay	7.8	0.37	Decrease	Decrease
Mann (1959)	18	Sandy loam	1.5	0.09	Increase	Increase
continued from Mann (1959)						
Charter et al. (1970)						
using Trefoil	30	Sandy loam	1.48	0.09	Same	Increase
using ryegrass		Sandy loam	1.48	0.09	Same	Decrease

Effect of Green Manures on Soil Physical Condition and Crop Performance

The authors next address two practical questions: Are green manures, used in a field situation, capable of improving soil physical properties in the same way that other forms of organic matter do? And the related question: Can the use of green manures improve crop performance?

Green Manures and Soil Physical Properties. The same characteristics evaluated in the first section of this paper are also evaluated here: aggregate distribution and stability, bulk density, moisture content and availability, and water movement. Though limited, the literature on green manure effects is generally consistent with that on the effects of organic matter per se.

Green Manures and Crop Performance. It is an accepted fact that improvements in soil physical condition create the potential for increased crop growth. It is, however, difficult to assess this relationship quantitatively, and to determine the degree of improvement necessary to effect a significant increase in crop yield. Researchers who have looked at corn production report that increased corn yields are associated with improvements in the physical condition of the soil. Due to limitations in experimental design, they were unable to differentiate the effect of enhanced soil fertility from the effects of an improved physical environment. One definitive point can be made: The benefits of green manuring on crop yield are most apparent during dry periods, particularly in rainfed production systems.

Conclusions

The authors' conclusions focus on the need for more creative research into the effects of green manures and soil organic matter. The number and complexity of factors involved necessitates the use of a new approach to research, one that is scientifically-based, and also holistic. Rather than following the traditional approach of controlling all but the few factors to be studied, the authors suggest that the interactions among *many* factors can be established by systematically holding one factor constant and measuring the effect of the green manure upon the others. These experiments must be conducted under different climatic conditions and over a long period of time. Though more expensive, this "holistic approach" is probably the only way to fully understand the benefits and challenges of green manuring.

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Contributed by Dave Chaney

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Fertilizers and soil borne diseases.

Huber, D.M.

Soil Use and Management 6(4):168-173. 1990

This review paper summarizes the influence of crop nutrition and fertilizers on soil-borne diseases in annual cropping systems. Effects of nutrients have been confirmed by: 1) evidence of how different fertilizer practices affect disease severity; 2) comparisons of the mineral concentrations in resistant and susceptible cultivars; and 3) correlation of other practices (organic matter additions, crop rotations, etc...) and conditions that influence mineral availability with disease incidence or severity. The influence of fertilizers has been directly attributed to effects on survival and germination of the pathogen, and/or effects on its penetration and virulence. As plant nutrition is improved, other benefits accrue including: enhanced disease resistance, disease escape from rapid growth rates, and root exudates that support a beneficial soil microflora. Numerous examples are cited with references.

Take-all of cereals *(Gaeumannomyces graminis)* has been extensively studied in this respect. A table of different soil conditions which increase or decrease this disease is provided. In general, take-all is more prevalent in alkaline, low-fertility soils and under conditions which increase nitrification such as nitrate application and liming. In contrast, eyespot *(Pseudocercosporella herpotrichoides)* and sharp eyespot *(Rhizoctonia cerealis)* are increased through top-dressing with ammonium.

Adjustment of pH is another important means of preventing plant disease mainly through its effect on nutrient availability and uptake. Maintaining a high soil pH through liming (and in some cases through application of calcium and/or nitrate) is recommended for management of:

- club root of crucifers
- fusarium wilt diseases
- root and hypocotyl rots (*F. solani, R. solani*)
- rot and damping off caused by *Pythium* spp.
- *Sclerotium rolfsii*
- aflatoxin in peanuts
- soft rot of potatoes, carrot, bean (*Erwinia* spp.)

Lowering soil pH through application of ammonium and manganese has been shown to decrease take-all of cereals, stalk rot of maize, common scab of potato, phymatotrichum root rot of cotton, verticillium wilt of various crops and various other diseases.

Contributed by Dave Chaney

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