ISA 81992

Agricultural use of organic amendments: A historical perspective

James F. Parr and Sharon B. Hornick

Abstract: *Agricultural research conducted in the United States since establishment of the U.S. Dept. of Agriculture and Land-Grant University System in 1862 has shown that regular and proper additions of organic materials are very important for maintaining the tilth, fertility, and productivity of agricultural soils, protecting them from wind and water erosion, and preventing nutrient losses by runoff and leaching. Several millennia earlier, Roman agriculturists were advocating crop rotations, green manuring, composts, legumes, farmyard manures, crop residues, wood ashes, seaweed, and sewage wastes for supplying humus and nutrients to restore or enhance soil productivity. Even earlier, Asian farmers also used these practices to maintain healthy and productive soils. Today the most serious problem in U.S. agriculture and agriculture worldwide is the widespread degradation of agricultural soils through erosion and the consequential decline in productivity. In view of how much information is available on the benefits of organic recycling on agricultural lands, one wonders why we aren't doing a better job of protecting and conserving our land resource base. We discuss strategies for using organic resources more effectively to achieve a more sustainable agriculture for the future.*

Key words: early agriculture, soil organic matter, erosion, soil quality, best management practices, municipal solid waste, sewage sludge, composting

Most books on soil and crop husbandry written in the United States during the past 100 years extol the virtues of soil organic matter, soil conservation, crop residue management, animal manuring, green manuring, cover crops, and crop rotations. They often refer to scientific research conducted by the U.S. Department of Agriculture and Land-Grant Universities, both established in 1862, that show that regular additions of organic amendments such as crop residues, animal manures, and green manures are essential for maintaining the tilth, fertility, and productivity of soils, for protecting them from wind and water erosion, and for preventing nutrient losses through runoff and leaching. The beneficial effects of these materials for improving the chemical, physical, and biological properties of agricultural soils have been extensively documented (U.S. Dept. of Agriculture, 1957, 1978, 1980; Allison, 1973; Hornick and Parr, 1987; Parr and Colacicco, 1987; Reganold et al., 1990).

Interestingly, many practices involving organic amendments, which we now call "best management practices," originated with early farmers about 2000 B.C. Such practices have been perfected down through the centuries as simple but powerful tools that could enhance agricultural sustainability indefinitely. It is ironic that as we approach the year 2000 A.D., the most serious threat to agriculture, both nationally and worldwide, is the continuing and alarming rate of soil degradation by wind and water erosion, and the concomitant loss of soil productivity.

Throughout this paper we use the term "organic amendment" for a wide array of organic materials, wastes, and residuals of either rural or urban origin that can improve soil properties and plant growth, and impart such beneficial effects over time that will improve soil productivity (U.S. Dept. of Agriculture, 1957). We offer a historical perspective on agricultural use of organic amendments, discuss the reasons for our current dilemma, and propose some strategies to enhance the value and effectiveness of these amendments as soil conditioners and organic fertilizers, that is, biofertilizers.

Early Developments

The Fertile Crescent

Scientists who have studied the origin of agriculture generally agree that it first began in the Near East about 8000 B.C. on a curving strip of land extending north through parts of Iran and Iraq, westward across northern Syria and southeastern Turkey, and southward through Lebanon and Israel and into the Nile Valley. This region has been referred to through the centuries as the Fertile Crescent. It was here that hunter-gatherers started to domesticate sheep and goats and began to cultivate the wild wheat and barley that abounded in this region (Leonard, 1973). Table 1 lists some significant events in the evolution of organized agriculture since then. Only a few significant milestones will be discussed here to emphasize how important it was to early farmers to regenerate their soils with organic amendments and residuals.

Farmers of forty centuries

Table 1 shows that farming began to develop in China, Mexico, and Peru between 4000 and 3000 B.C. In the early

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1900s, F.H. King, Chief of the Division of Soil Management, U.S. Dept. of Agriculture, became concerned about the sustainability of farming practices in the United States and whether we could maintain our soils' fertility and productivity for future generations. He was curious how farmers in the Far East did this despite such high population densities. In 1911, he traveled extensively in China, Korea, and Japan. In King's own words:

> We desired to learn how it is possible after twenty and perhaps thirty or even forty centuries, for their soils to be made to produce sufficiently for the maintenance of such dense populations as are living now in these three countries. (King, 1911, p. 2)

King found that the key to maintaining a permanent and sustainable agriculture through the centuries in China, Korea and Japan was the regular and extensive recycling of a vast array of organic materials as soil conditioners and biofertilizers. These materials included animal manures, green manures, nightsoil, crop residues, canal mud, wood ashes, tree leaves, aquatic weeds from canals, wild grasses, urban sewage and street refuse. Many of these materials were composted to destroy weed seeds and potential human and plant pathogens, to enhance their nutrient availability, to suppress malodors, and to facilitate storage, transport, and application to land. Organic recycling allowed farmers to maximize their crop production with negligible soil erosion and nutrient runoff.

Table 1. Milestones in the development and evolution of organized agriculture.[1]

Years	Significant Events
9000 - 8000 BC	Sheep domesticated in Near East.
8000 - 7000	Goats domesticated in Persia. Wheat and barley cultivated in Near East Pattern of village life developed in Near East.
7000 - 6000	Cattle domesticated in Near East.
6000 - 5000	Agriculture replaced hunting in Europe. Corn cultivated in Mexico.
4000 - 3000	Potatoes grown in South America. Rice cultivated in Far East. Farming developed in China, Mexico, and Peru.
3000 - 2500	Plow developed in Near East
2000 - 1500	Advanced farming developed in Near East.
500 BC - 500 AD	Advanced farming developed under Greeks and Romans. Many farming textbooks written. Fallowing, manuring, composting, and crop rotations advocated. Wheeled plow developed, fitted with moldboard.
500 - 1000	The Dark Ages. Little new knowledge on farming. Few new textbooks written. Roman farming practices continued.
1000 - 1500	The Middle Ages. Increased livestock husbandry. Some development of fallowing, manuring, and crop rotation practices. Primitive moldboard plow developed.
1500 - 1600	Invention of printing press facilitated spread of knowledge on farming. Improved moldboard plow developed.
1600 - 1700	Corn, potatoes, tobacco introduced to Europe from America. Knowledge of chemical agriculture advanced.
1700 - 1800	Mechanization of agriculture advanced.
1862	USDA and Land-Grant University System established.

[1] Compiled from MacKay (1950), Fussell (1965), White (1970), and Leonard (1973).

Agriculture in the Near East

For about 5000 years after farming began in the Near East, the early farmers planted seeds by dibbling, that is, by placing seeds in holes made with a pointed stick. This practice still exists among primitive peoples in remote regions. With the invention of the plow in the Near East (3000 - 2500 B.C.), agriculture began to develop rapidly since more land could be cultivated. According to MacKay (1950), by 2000 B.C. agriculture in the Near East had become relatively advanced in the production of livestock and the growing of cereals, vegetables, and tree crops. These farmers had learned that animal manures and nitrogen-fixing legumes, including vetches, alfalfa, and peas, could help maintain soil fertility.

Greco-Roman agriculture

Agricultural technologies from the Near East were introduced to Greece by Persian invasions beginning about 500 B.C., and additional knowledge was obtained by the Greeks two centuries later from the conquests of Alexander the Great in Babylonia and Egypt (Fussell, 1965; White, 1970). The dispersal of new agricultural crops and technologies reached its zenith during the Roman Empire after their conquests of Greece, the Near East, and much of Europe.

The power and glory of Rome and its empire can be attributed considerably to the stability and productivity of its agricul-

ture. The most prominent Roman agriculturists and technical writers included Cato the Elder (234 - 149 B.C.), Varro (116 - 27 B.C.), Columella (ca. 25 A.D.), Pliny the Elder (23 - 79 A.D.) and Palladius (ca. 450 A.D.). All these authorities made major contributions to the art and science of practical farming, and emphasized the benefits to agriculture that could be derived from organization, management, and conservation of natural resources, especially soil and water (Fussell, 1965; White, 1970). They were extremely prolific writers who published numerous textbooks on all aspects of agriculture, including animal husbandry, crop husbandry, and soil and water management. Their teachings and writings led to significant advances in mechanization, tillage systems, fallowing, crop rotations, multiple cropping techniques, water conservation, and drainage. They emphasized the importance of maintaining soil fertility through such practices as animal manuring, composting, green manuring, liming and marling, recycling of crop residues, and applying sewage wastes, wood ashes, and seaweed.

After the fall of the Roman Empire, the Dark Ages (500-1000 A.D.) produced little new information on farming, and no new textbooks were written. Farmers continued using the methods and techniques established by the early Roman agriculturists. The Middle Ages (1000 - 1500 A.D.) also contributed very little to the advancement of agricultural science and technology, although there was a shift toward increased livestock husbandry in northern and western Europe, and some improvement in implements. Wars, famine, and disease also were rampant during this period, and certainly contributed to the slow progress (Fussell, 1965). Only after the Renaissance started did agricultural science and technology begin to make significant advances again.

The importance of soil quality

The Soil Science Society of America (1984) has defined soil quality as an inherent attribute of a soil that is inferred from soil characteristics or direct observations. Such characteristics and observations allow some conclusions about a soil's inherent fertility and ability to resist compaction, crusting, and erosion. The term is often used to refer to a soil's relative or potential productivity.

An early reference to the importance of soil quality was attributed to Xenophon, an early Greek philosopher (430 - 355 B.C.), who insisted that successful farming depended on the farmer's intimate knowledge of his land and soil, the quality of which he could judge by the natural ecology. He wrote that if the vegetation was abundant and the soil supported ample growth of wild fruits and weeds, it would produce good crops if it was well tilled and managed (Fussell, 1965). This method of estimating soil quality and classifying the production capability of soils is still used today. The simple terms for classifying soils during the Greco-Roman period were "black", "sandy", "clayey", "dry", and "wet".

In his assessment of how much importance early farmers attached to soil quality, Allison (1973, p. 3) wrote:

> Soil organic matter has over the centuries been considered by many as the elixir of life—in this case of plant life. Ever since the dawn of history, some eight thousand or more years ago, man has appreciated the fact that dark soils, commonly found chiefly in the river valleys and broad level plains, are usually (but not always) productive soils. He also realized at a very early date that color and productivity [of soils] are commonly associated with organic matter derived chiefly from decaying plant materials.

Since the time of Xenophon, the term "soil quality" has been largely (if not exclusively) equated with soil productivity. However, today in the United States the term has taken on a much greater meaning because of the strong sustainable agriculture movement (Reganold et al., 1990).

Thus, while soil productivity is still a part of soil quality, the concept has been broadened to include attributes of environmental quality, human and animal health, and food safety and quality (Parr et al., 1992). Currently, in the U.S. there is great interest in how soil quality can be quantified into indexes that can be used as a tool to characterize the status of soil health, and to serve as early warning indicators of soil degradation and the need for remedial measures (Parr et al., 1992).

Most definitions of sustainable agriculture agree that it is a concept or goal of developing farming systems that over the long term are productive and profitable, environmentally sound, and energy conserving, and that enhance health and safety. Low-input alternative methods and skilled management can contribute significantly to achieving this goal (Parr et al., 1990). The relationship between the goal of sustainable agriculture and the strategy of alternative agriculture is illustrated in Figure 1. Most of the alternative practices cited involve the addition of organic amendments that would improve soil tilth, fertility, and productivity. In a recent paper, Parr et al. (1992) proposed that soil quality provides a vital link between alternative agriculture and sustainable agriculture, and that soil quality is the key to long-term agricultural sustainability.

Soil Erosion—A Major Obstacle to a Permanent Agriculture

In 1938-39, some three decades after F.H. King's historic trip to the Orient, W.C. Lowdermilk, then Assistant Chief of USDA's Soil Conservation Service, traveled to Europe, North Africa and the Near East to study the status of lands that had been cultivated for centuries and even millennia, and to obtain information that could help to solve soil erosion and land use problems in the United States (Lowdermilk, 1953).

He found that many ancient cities and empires of the Fertile Crescent that once had a stable and productive agriculture had become virtual graveyards. Lowdermilk gave several reasons for the decline of these once great civilizations. At first, agriculture was confined mainly to the alluvial plains and valley bottom lands. As populations increased, forests were cut and the poorer quality sloping lands were cultivated intensively. The result was extensive erosion, sedimentation of the Tigris and Euphrates Rivers and tributaries, siltation of irrigation canals, and salinization of poorly drained irrigated lands. Lowdermilk (1953, p. 27) concluded that:

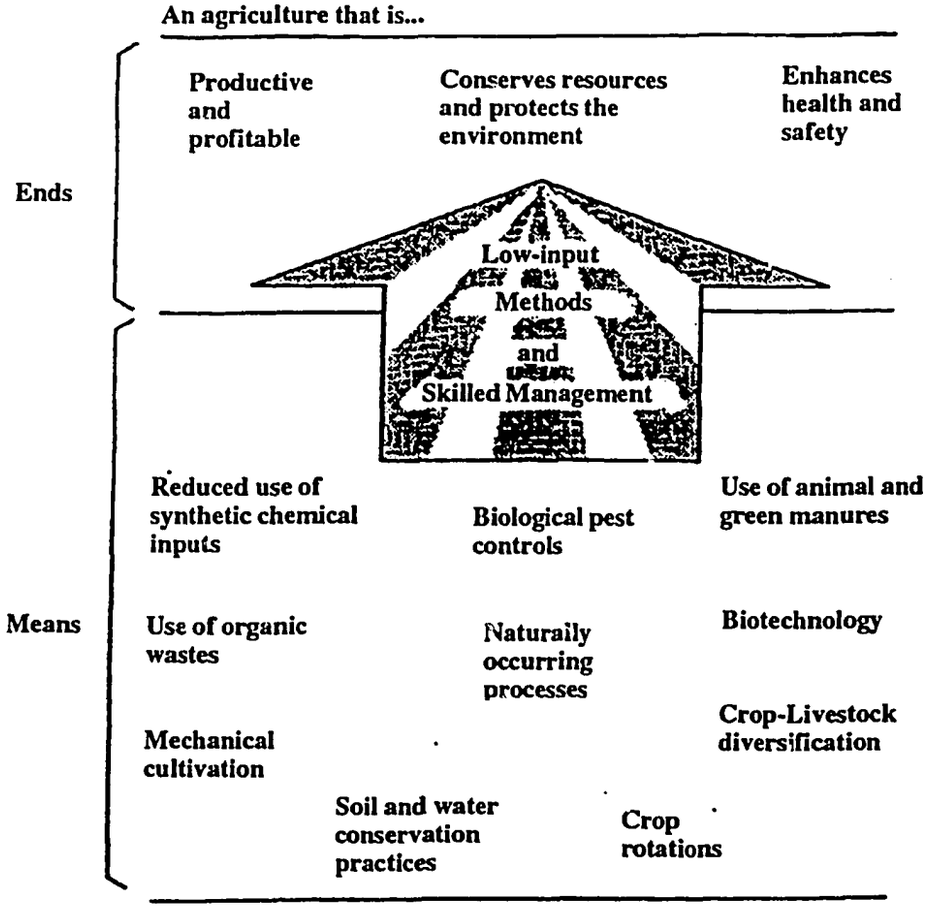

Figure 1. A current concept of sustainable agriculture in the United States showing the ends or objectivs and the means of achieving them through low-input methods and skilled management.

> A solution to the problem of farming sloping lands must be found if we are to establish an enduring agriculture in the United States. We have only about 100 million acres of flat alluvial land where the erosion hazard is negligible, out of 460 million acres of land suitable for crops. Most of our production comes from sloping lands where the hazard of soil erosion is ever present. This calls urgently for the discovery, adaptation, and application of measures for conserving our soils.

Meanwhile, more than four decades after Lowdermilk voiced his concerns, soil erosion by wind and water, and the associated loss of soil productivity and soil quality, remains our most serious agricultural and environmental problem. For example, Brown and Wolf (1984) estimated that the worldwide rate of topsoil loss from erosion is about 0.7% per year. In 1982 USDA's Soil Conservation Service estimated that about 2.3 billion tons of topsoil per year was being eroded from U.S. cropland by wind and water (Brosten, 1988). According to Brosten (1988) this is enough soil to fill a freight train of 100-ton hopper cars 241,761 miles long, almost ten times the earth's circumference. Brosten suggests that a major shift from conventional tillage to conservation tillage practices such as no-till, strip tillage, ridge tillage, mulch tillage, and reduced tillage, could significantly reduce soil erosion of our croplands.

These statistics are alarming in view of the extensive research that has been conducted in the U.S. on the mechanics, measurement and control of soil erosion. It is also of concern because most of our agricultural soils have been farmed for less than 150 years, many of which have already lost much, if not most, of their topsoil (Gibbons and Wilson, 1984). Obvious questions then are how and why this has happened. Table 2 lists some reasons that conservation farming methods have not been adopted and practiced by early and more recent farmers. Several of these are discussed in the following section.

Changes in Farming Systems in the United States since 1900

For the first half of this century, most farms in the U.S. were mixed crop-livestock operations. Farmers produced forages and feed grains for their animals through long-term crop rotations that did

Table 2. Reasons that conservation farming methods have not been more widely adopted and practiced over time.

1. Lack of skilled management.
2. Lack of incentives and motivation.
3. Abundance of cheap and available land.
4. Intensive production of cash grain crops to enhance short-term economic gain.
5. Government farm programs have discouraged conservation farming.
6. Shift from mixed crop-livestock operations to high chemical-intensive monoculture cash grain systems.
7. Population pressures have caused increased cultivation of marginal lands.
8. Favorable commodity prices have encouraged cultivation of marginal lands.

not require large input purchases each year. Soil productivity was maintained by crop rotations, including nitrogen-fixing legumes, and the return of crop residues and animal manures to the land. Few pesticides were used. Weeds, insects, and plant diseases were controlled mainly through crop rotations, mechanical cultivation, and biological means, such as natural predators (National Research Council, 1989).

It is ironic that about the same time Lowdermilk (1953) published the findings of his Near East tour and expressed his concern for protecting sloping farmlands in the U.S., farmers in this country began to shift from mixed crop-livestock operations to highly specialized cash grain monocultures. Monoculture, or the practice of growing the same crop on the same land through at least two crop cycles, is most important in the U.S. for wheat, corn, soybeans, cotton, sorghum, and tobacco. The three main factors that propelled U.S. farmers toward monoculture were advanced large-scale mechanization, improved crop varieties, and the availability of low-cost chemical fertilizers and pesticides (Power and Follett, 1987). These enabled farmers to shift from crop rotations and animal related enterprises to monoculture cash grain crops, which significantly increased their net return. Other advantages of monoculture are more efficient use of machinery, lower labor costs, and simplified marketing (Power and Follett, 1987).

Government programs and farm subsidies greatly reduced the risk of specialization. However, they also encouraged the separation of feed grain production from the livestock component, which was rapidly transformed into a feedlot industry. This resulted in the decline of two vital soil and water conservation practices: the return of animal manures to the land, and the rotation of grain crops with grasses and legumes. Consequently, farmers who specialized in cash grain production had to increase their inputs of chemical fertilizers and pesticides to compensate for the lost benefits of crop rotations.

Thus, for the last four decades U.S. agriculture has substituted machinery, pesticides, chemical fertilizers, irrigation, and energy in place of crop and livestock diversity, labor, land, and traditional farm management. This, in turn, has led to many of the current problems associated with U.S. agriculture, including excessive soil erosion, loss of soil productivity, pollution of surface and groundwater by sediment and agrichemicals, health risks and environmental impacts of pesticides, and food safety and quality. It has also raised questions concerning the long-term sustainability of our farming systems.

Soil Organic Matter: Its Role and Value in Crop Production

A very comprehensive treatment of the role of organic matter on soil productivity and crop production is that of Allison (1973). Even a cursory reading of this book leaves no doubt that the key to soil fertility and productivity is soil organic matter from proper and regular additions of organic amendments. A summary of the beneficial effects of soil organic matter on soil properties is shown in Table 3. All the effects shown, including nutritional, chemical, physical, and biological, extend over time. For example, certain plant nutrients such as nitrogen, phosphorus and sulfur contained in organic materials are in organic forms and not available to plants until these materials are decomposed by soil microorganisms. The soil chemical and physical properties also are enhanced as decomposition proceeds. For example, as soil microorganisms use organic wastes or crop residues as a carbon source, they produce polysaccharides that can bind soil particles together into stable aggregates, thereby improving tilth and reducing soil erosion.

Table 3. Beneficial effects of soil organic matter on soil properties (Allison, 1973).

Soil Property Affected	Beneficial Effect
Nutritional	
Micronutrients	Provides Cu, Mn, Zn, B, Cl, Mo
Macronutrients	Provides O, H, C, N, P, S, Fe, Ca, Mg
Chemical	
Cation exchange capacity	Increases
Buffering capacity	Increases
Chelating capacity	Increases
pH	Alleviates acidic and alkaline conditions
Physical	
Soil aggregation	Increases
Aggregate stability	Increases
Water holding capacity	Increases
Soil porosity	Increases
Water infiltration	Increases
Water percolation	Increases
Soil crusting	Decreases
Bulk density	Decreases
Biological	
Beneficial microorganisms	Produces polysaccharides/antibiotics
	Increases nutrient availability
	Suppresses plant pathogens
	Decomposes organic wastes
Earthworms	Populations increase

The application of organic materials to soils also increases the efficiency of chemical fertilizers. For example, a 50-year study (1890-1940) at Sanborn Field, Columbia, Missouri, showed that a combination of animal manure and chemical N fertilizer resulted in higher yields of corn, wheat, and hay, and higher N-use efficiency, than from either N source applied alone (Smith, 1942).

The true value of organic materials as biofertilizers and soil conditioners is often misunderstood (Parr and Colacicco, 1987). The simplest and most common way to estimate the value of organic materials is to consider them as partial substitutes for chemical fertilizers that would otherwise have to be purchased. This is done by assessing the current market value of the plant nutrients they contain, especially the macronutrients (nitrogen, phosphorus, and potassium). Many organic materials contain other macronutrients and micronutrients that can contribute significantly to higher crop yields (Table 3). When any of these nutrients substitute for essential production inputs, the value of a particular organic material increases accordingly. An additional benefit of many organic materials is that they have a greater residual effect on soil fertility than most chemical fertilizers because they release N and P slowly. Thus, a significant portion of the true value of organic materials is their ability to increase the yield of succeeding crops (Parr and Colacicco, 1987).

The Dynamics of Soil Productivity

An important relationship often overlooked with agricultural soils is illustrated in Figure 2. Usually, degradative processes such as soil erosion, losses of nutrients by runoff, and organic matter depletion occur simultaneously with the beneficial effects of conservation practices such as crop rotations, conservation tillage, and recycling of animal manures and crop residues (Hornick and Parr, 1987). As soil degradative processes intensify, soil productivity decreases concomitantly. Conversely, soil conservation practices tend to slow these degradative processes and increase soil productivity. Thus, the potential productivity of a particular soil is the result of ongoing degradative processes and applied conservation practices. Generally, the most serious degradative processes are soil erosion and associated depletion of plant nutrients and organic matter.

On our best agricultural soils—that is, gently sloping, medium-textured, well-structured soils with a deep, well-drained profile—a high level of productivity can be maintained by a few essential conservation practices that readily offset most degradative processes. However, soil conservation practices must be maximized to counteract further degradation on marginal soils of limited capability, such as steeply sloping, coarse-textured, poorly-structured soils that are depleted of nutrients and have a shallow, poorly-drained profile. Thus, a truly sustainable farming system is one in which the beneficial effects of various conservation practices equal or exceed the harmful effects of degradative processes. Organic wastes and residues offer the best way to restore the productivity of severely eroded agricultural soils or to reclaim marginal soils (Hornick and Parr, 1987).

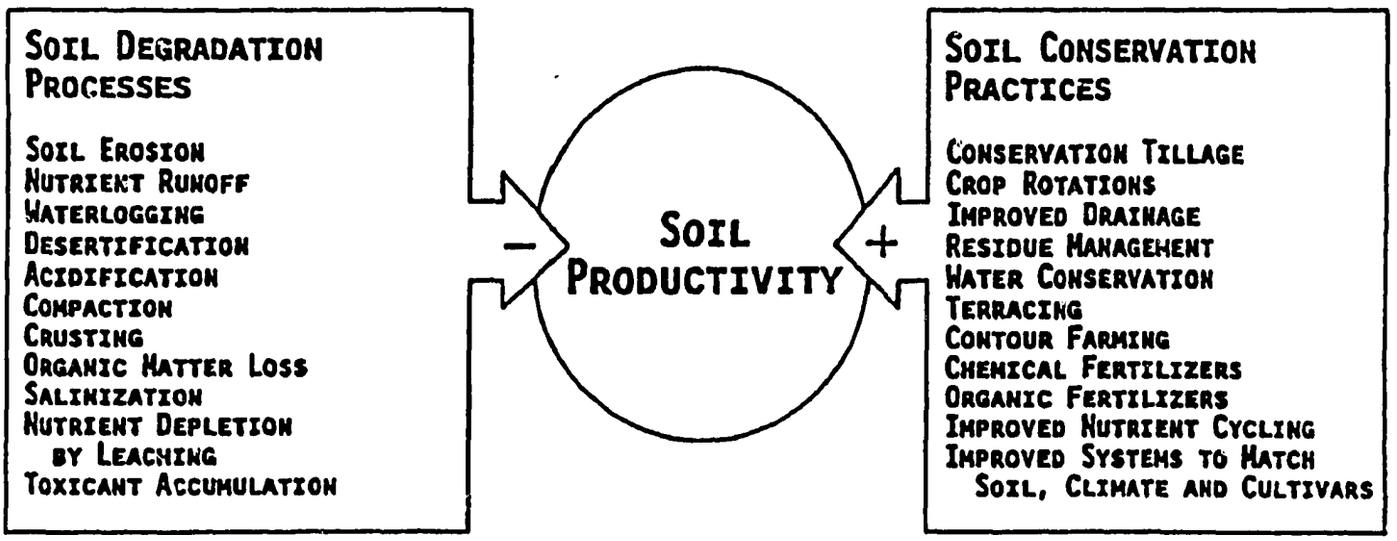

Figure 2. Soil productivity is the result of interactions between soil degradative processes and soil conservation practices (Hornick and Parr, 1987).

Use of Municipal Wastes as Soil Conditioners and Biofertilizers

The two principal waste streams that have emerged with municipal development are sewage sludge and effluents, and solid waste or garbage. For centuries municipal wastes have been used as soil conditioners and biofertilizers to enhance the productivity of agricultural lands. During the last two decades, considerable research has been conducted to ensure that sewage sludges could be used safely and beneficially on cropland (U.S. Environmental Protection Agency, 1989a; Chaney, 1990a,b).

Composting has received considerable attention as an effective way to transform raw, unstable municipal wastes into acceptable and valuable soil amendments. For example, in the early 1970s USDA scientists with the Agricultural Research Service at Beltsville, Maryland, developed a process for rapid composting of sewage sludges that has been adopted by many U.S. cities and municipalities, in place of ultimate disposal methods such as incineration, landfilling, and ocean dumping (Willson et al., 1980; Hornick et al., 1984). More than 30% of the sewage sludge produced in the U.S. is now being used beneficially on agricultural and nonagricultural land as compost, or by land spreading and liquid injection (U.S. Environmental Protection Agency, 1990a).

A major problem in the U.S. and many other countries is how to manage our municipal solid waste (MSW) in view of the increasingly restrictive environmental regulations against ultimate disposal methods (Parr and Hornick, 1992). Only about 10% of our MSW currently is recycled, while 10% is incinerated and 80% is landfilled. The situation is critical for many cities and municipalities because landfills are filling up, and the development of new landfills is environmentally objectionable and extremely expensive. A substantial reduction in both the number and remaining capacity of U.S. landfills is projected for the year 2000 (Parr and Hornick, 1992). The current annual U.S. production of MSW is about 165 million dry metric tons, or a per capita annual production of about 600 kg (U.S. Environmental Protection Agency, 1989b). The estimated production of MSW will increase to about 200 million tons by the year 2000 and to 230 million tons by 2010 (U.S. Environmental Protection Agency, 1990b).

The kind and amount of materials that comprise the nation's MSW stream are shown in Table 4. The largest single component is paper and cardboard products, which accounts for 35%, followed by yard waste (grass clippings, leaves, and trimmings from trees and shrubs) at about 20%. These two waste fractions combined with food waste (8.5%) and discarded wood products (4.2%) account for approximately two-thirds of our MSW, most of which goes into landfills. All four of these waste materials are biodegradable and could be composted or cocomposted for beneficial use as soil conditioners and biofertilizers on agricultural and nonagricultural lands. Metals, glass, and plastics comprise about 25% of our MSW and have considerable recyclable value, especially when municipalities introduce source separation or curbside collection programs.

Table 4. Percent composition of materials by weight in U.S. municipal solid waste (U.S. Environmental Protection Agency, 1990b).

Material	Composition (%)
Paper and cardboard	34.2
Yard waste	19.9
Food waste	8.5
Metals	8.1
Glass	7.1
Plastics	9.2
Wood	4.2
Rubber and leather	2.9
Textiles	2.5
Other	3.4

Recent Legislation Concerning the Agricultural Use of Residuals

There have been several recent legislative initiatives by the U.S. Congress that are relevant to agricultural use of rural and urban wastes for improving the productivity, quality, and sustainability of our soils.

The Food and Agriculture Act of 1977 (PL 95-113)

This Act, also known as the 1977 Farm Bill, required that USDA submit a report to the Congress on "the practicability, desirability, and feasibility of collecting, transporting, and placing of organic wastes on land to improve soil tilth and fertility." This is the first known official request for an inventory of organic waste production in the U.S. Information was requested on the kinds, amounts, and availability of organic materials that could be used as soil conditioners and biofertilizers for improving soil productivity and counteracting excessive soil erosion. A summary of the USDA Report is shown in Table 5 (U.S. Dept. of Agriculture, 1978). The total annual production of both rural and urban wastes in 1977 was approximately 730 million dry metric tons. More than 90% of the total amount consists of crop residues (53.7%), animal manures (21.8%) and municipal solid waste (18.1%). Crop residues and animal manures already are being recycled on land to a much greater extent than other wastes, and are not likely to become significantly more available. Since these data were compiled, the amount of sewage sludge applied to land has increased from about 23% to more than 30%. MSW offers the greatest potential for increased agricultural use as soil conditioners and biofertilizers.

The USDA Report concluded that these wastes represent a national resource of significant economic value, and that there is a growing shortage of good quality organic wastes for use in maintaining and improving the productivity of our agricultural soils.

The Food Security Act and Agricultural Productivity Act of 1985 (PL 99-198)

These Acts made up the 1985 Farm Bill, which provided for the Conservation Reserve Program (CRP) that was implemented in 1986. The CRP called for the removal of up to 45 million acres of highly

Table 5. Annual U.S. production of organic wastes in 1978 and amounts that were recycled on land (U.S. Dept. of Agriculture, 1978).

Category of Organic Waste	Total Production		Amount Recycled on land
	10^6 Dry Metric Tons	% of Total	
Crop Residues	391	53.7	68
Animal Manures	159	21.8	90
Municipal Solid Waste	132	18.1	1
Logging/Wood Products	32	4.5	5
Industrial Organic	7.5	1.0	3
Sewage Sludge	4.0	0.5	23
Food Processing	2.9	0.4	13
TOTAL	728.4	100.0	

erodible U.S. cropland from agricultural production. Land that is assigned to the CRP is under a 10-year bond with USDA, during which time the landowner receives annual payments for either planting trees or seeding the land to grasses and maintaining a continuous cover. The original intent of CRP was to retire a large amount of these fragile lands from crop production permanently. However, a substantial amount could return to cropland as early as 1995. If they are cropped again, the best way to protect them against further degradation by wind and water erosion is proper and regular additions of organic amendments. Moreover, since some of these lands will not produce sufficient amounts of crop residues to control erosion, the most feasible way to protect them may be to use urban or other off-farm wastes.

The 1985 Farm Bill also authorized the USDA to conduct research and education programs on alternative agriculture, or more specifically on low-input or sustainable farming systems (U.S. Dept. of Agriculture, 1988). The concept that has emerged is one of low-input/sustainable agriculture or LISA, which has contributed to the adoption of management practices by farmers that enhance the production and use of organic amendments (e.g., crop residues, green manures, and animal manures) that can improve soil productivity and the sustainability of farming systems.

Food, Agriculture, Conservation, and Trade Act of 1990 (PL 101-624)

This Act, also known as the 1990 Farm Bill, provides for a National Composting Research and Extension Program (Section 1456). Specifically, it requires USDA to "compile information on appropriate methods of composting agricultural wastes from the production, processing, and distribution of food, fiber, forestry, and fish products, and the potential use of such compost." It further directs USDA to:

> Conduct research on the potential uses for compost derived from animal wastes, and from other waste streams as appropriate, and identify uses for such compost, including the potential for marketing such product. Such research shall also include evaluation of the application of compost derived from agricultural wastes on soil, plants, and food and fiber crops.

These initiatives show the concern that environmentalists, farmers, consumers, conservationists, and the public have for maintaining and restoring the productivity of our agricultural lands. Emphasis on recycling and processing of selected organic wastes from the rural/urban interface for safe and beneficial use on land is likely to increase considerably in the future.

Summary and Conclusions

Most "best management practices" that we recommend to today's farmers to enhance the productivity of their croplands were developed by farmers many centuries ago. Greek and Roman agriculturists wrote extensively of the benefits of crop rotations, fallowing, mulching, multiple cropping, animal manuring, green manuring, composting of organic wastes, and liming. The value of recycling organic wastes and residuals from both rural and urban sources became widely recognized as the best way to maintain and improve the tilth, fertility, and productivity of agricultural lands. Today, soil organic matter still remains as the undisputed key to soil productivity. Through the centuries, farmers often have neglected or even abandoned the practice of recycling organic residuals when they switched to intensive tillage and monoculture systems to increase production and profitability. They have always paid dearly for this neglect, because it has led to excessive soil erosion, depletion of soil fertility, nutrient runoff, and loss of soil organic matter, all of which have culminated in the often irreparable loss of soil productivity.

In the United States, soil erosion by wind and water, and the associated loss of soil productivity and impairment of soil quality, remain our most serious agricultural and environmental problems. Although soils in some parts of the world have been cultivated and conserved for more than forty centuries, most U.S. agricultural soils have been farmed for less than 150 years. Unfortunately, because of poor farming practices, many of them have been highly eroded, losing much of their topsoil and potential productivity.

Recent federal legislation has called for action programs to encourage the proper and regular addition of rural and urban wastes, and their safe and beneficial use, for improving the productivity, quality, and sustainability of our agricultural lands. National inventories of the kinds, amounts, and availability of organic materials that could be used as soil conditioners and biofertilizers should be conducted and updated every five years. A National Composting Research and Extension Program that was called for in the 1990 Farm Bill

could go a long way toward providing valuable organic materials for maintaining and restoring the tilth and fertility of our soils. Practical and reliable on-farm composting methods will be needed to ensure the success of this program. Highly erodible croplands that are currently under the Conservation Reserve Program would also benefit from the proper and regular application of composts or other amendments when these lands are returned to crop production.

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