
TECHNICAL PAPER #8

UNDERSTANDING SOIL PREPARATION

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PREFACE

This paper is one of a series published by Volunteers in Technical Assistance to provide an introduction to specific state-of-the-art technologies of interest to people in developing countries. The papers are intended to be used as guidelines to help people choose technologies that are suitable to their situations. They are not intended to provide construction or implementation details. People are urged to contact VITA or a similar organization for further information and technical assistance if they find that a particular technology seems to meet their needs.

The papers in the series were written, reviewed, and illustrated almost entirely by VITA Volunteer technical experts on a purely voluntary basis. Some 500 volunteers were involved in the production of the first 100 titles issued, contributing approximately 5,000 hours of their time. VITA staff included Leslie Gottschalk and Maria Giannuzzi as editors, Julie Berman handling typesetting and layout, and Margaret Crouch as project manager.

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UNDERSTANDING SOIL PREPARATION

by VITA Volunteer Paul J. Abrahams

I. INTRODUCTION

The purpose of soil preparation is to develop a planting medium that will foster the best possible growth of agricultural crops while preventing the deterioration of the land through erosion,

destruction of soil structure, or nutrient loss. The soil preparation system used must be economical, since a large part of the expense in raising a crop occurs before the seed is ever placed in the ground.

OBJECTIVES OF SOIL PREPARATION

The immediate goals to be accomplished in soil preparation are:

*** destruction of weeds,**

*** incorporation of organic material,**

*** incorporation of fertilizers and lime, and**

*** development of the proper seed bed.**

Destruction of Weeds

Weeds compete with agricultural crops for moisture, nutrients, and sunlight. They also hinder harvesting, particularly if they are viney types. Some weeds are poisonous to people and animals. Proper soil preparation coupled with effective crop rotation will prevent the emergence of weeds at the time of planting. This allows crops at their most tender stage to grow without competition. Careful soil preparation will also retard the growth of weeds as the crops develop, making cultivation and harvesting easier.

Incorporation of Organic Material

Organic matter has many beneficial qualities that aid plant growth:

(1) the ability to retain water for the use of crops during drought;

(2) the improvement of soil tilth (structure); and

(3) the ability to hold nutrients in the soil instead of being leached out by rain.

The natural coverings of soil are forests or grasses, which yearly add organic matter to the soil as dead wood, leaves, and roots. Whenever soil is made bare by the removal of its vegetative cover the level of organic matter will be reduced. In addition, soil microbes, such as bacteria and fungi, and larger animals, such as insects and worms, are constantly consuming organic material.

When the forest or grassland is destroyed to grow crops, the natural additions must be replaced by the farmer's efforts. Organic matter is added by working animal manure, compost, straw, or leaves into the soil, or by plowing under green manure crops such as clovers, vetch, or rye. Crop residues such as stalks, vines, and leaves will add to the organic matter level.

Incorporation of Commercial Fertilizers and Lime

Unless green manure crops are used or large amounts of animal manure can be added to the soil, commercial fertilizers must be used to maintain proper soil fertility. As a general rule, one must add plant nutrients in an amount equal to that removed in harvested crops. (See Table 1.) If this is not done, the fertility of the soil will drop slowly, causing a decrease in subsequent yields. Phosphorus and potassium may not have to be replaced at the same rate as nitrogen. Soil tests to determine the needed amounts of these nutrients can save on fertilizer expenses.

It would take the addition of approximately five tons of cattle manure per acre to replace the nutrients removed from the soil by the harvesting of 100 bushels of corn. A 50-bushel wheat crop would require four tons. That is equivalent to the addition of 11,000 kg per hectare of manure on corn and 9,000 kg per hectare of manure on wheat.

It would be preferable if all nutrients could be added as manure because this would greatly increase the organic matter content of the soil. However, the large amounts of manure needed may be difficult to obtain. In general, it may be more efficient to manure the garden or speciality crops and use commercial fertilizers on field crops.

Proper soil fertility helps prevent erosion. Fertile land produces more and bigger plants in a given area than nutrient-poor

Table 1. Fertilizer Amounts Needed to Replace Nutrients

Removed by Harvesting Corn Grain and Wheat Grain at Good Yields

Amount of Fertilizer

	Nitrogen (N)	Phosphorus Pentoxide ([P.sub.2][O.sub.5])	Potassium Oxide ([K.sub.2]O)
Corn			
At 100 bushels per acre	**80 lb**	**35 lb**	**21 lb**
At 6200 kilograms per hectare	**90 kg**	**39 kg**	**24 kg**
Wheat			
At 50 bushels per acre	**70 lb**	**26 lb**	**13 lb**
At 3400 kilograms per hectare	**79 kg**	**29 kg**	**15 kg**

land. Growing crops protect the soil against beating rains. Crop residues incorporated into the soil increase the level of organic material.

Lime must be added to most soils periodically to neutralize the acidifying effect of commercial fertilizers. Even land that does not need fertilizer usually requires lime because growing plant roots cause the soil to become more acid. If possible, a soil testing laboratory should be consulted to determine the need for soil additives.

Development of the Proper Seed Bed

The development of a suitable seed bed will ensure good seed germination, allow rapid root growth, and aid in mechanical cultivation.

The best soil is loose, having a crumb structure that breaks easily into small pieces approximately three to seven millimeters in diameter when handled. The deeper this crumb condition is maintained in a soil the better. Crumb-type soil fits snugly around the young seed with no air gaps. This allows the seed to be bathed in moisture. Roots will grow readily into this type of soil. Crumb soil is easy to cultivate with machinery or by hand. Tractor or animal-drawn cultivators can gently roll the crumbs up to plants, easily killing weeds.

The worst type of soil is one full of hard clods, larger than three centimeters in diameter. The larger the clods the more difficult the soil is to work. Seeds covered by clods are surrounded by air pockets, causing them to dry out too soon. The young plant has a hard time breaking through clods and many will never get to the surface. Roots have a similar problem.

Mechanical cultivators will push large clods toward the young growing plants, breaking many. Moreover, clods contain many weed seeds, which will still germinate if the clod is merely rolled around by the cultivator. Young grass and other weeds will not be killed unless their roots are broken free from the surrounding soil. This cannot be accomplished by rolling clods (Figure 1).

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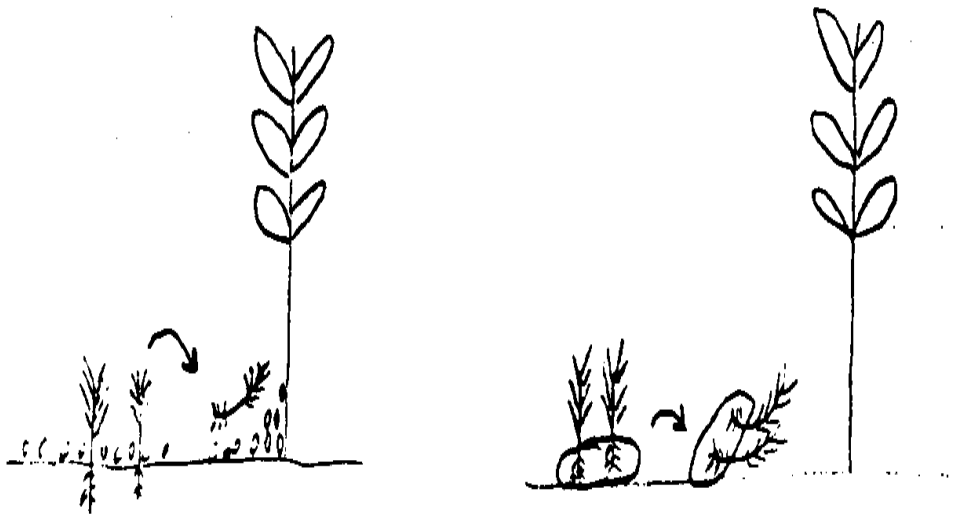

Cultivating Crumbs
Weed Roots Exposed

Cultivating Clods
Weeds Still Grow

Figure 1

Clods are formed primarily by working (plowing, harrowing, or cultivating) soil when it is still wet. They are particularly noticeable when a moldboard plow is used on wet ground. Large smooth-sided clods are turned up by the shearing action of the plow. When these clods dry out, they are almost impossible to break down--even with extra harrowing. The less organic matter a soil contains, the more likely it is to form clods when plowed.

Humus in the soil prevents soil particles from cementing into clods.

The simplest way to develop a good crumb structure in a field is by growing thickly planted legume and grass sod crops in rotation with the field crop. Over time, the roots of legumes and grasses will crumble even a hard soil to a great depth. The roots also open up passages in the soil for the movement of air and water. The beneficial effect of these sod crops will last several years after they have been turned under. And livestock can graze on the growing grasses.

To ensure a good crumb structure as well as a good seed bed:

1. Rotate sod crops with field crops.

2. Add as much manure and other organic material as possible.

3. Wait until wet soil is no longer sticky before working. Check by squeezing a handful of soil in your hand. Soil that is too wet will pack together in a sticky lump and leave your hand wet. Soil that is dry enough to plow will crumble again easily when pressure is released.

II. SOIL PREPARATION OF AGRICULTURAL LAND

CATEGORIES OF AGRICULTURAL LAND

Several factors affect the method of soil preparation:

*** length of growing season**
*** annual distribution of rainfall**
*** soil type**
*** slope of the land**
*** type of crops to be produced**
*** size of farm**
*** level of technology**

Given the large variation in geographical conditions and cultural practices encountered in food-growing, it is easiest to assign agricultural lands into three basic categories:

1. Large-scale agriculture on fertile, level low-lands

2. Intermediate-scale agriculture on erodible uplands of varying fertility

3. Gardens

Much of the world's best crop land is located along the flood-plains of major rivers. Other highly productive areas include lands that lie on the beds of ancient lakes and oceans, which have dried up or moved. These lands are flat and highly fertile. In many countries, such areas have been divided into large grain and soybean farms that require high levels of technology.

Because these lands are level, erosion is relatively limited. The lands are also often wet, discouraging livestock production. Even where livestock can be raised in most areas, such land is too valuable to be used as pasture; crops bring a better return per acre. All these factors have often led to a mono cropping system, with fields left fallow, between the yearly cropping. In the short run, it is more economical under these conditions to add commercial fertilizer than to use green manure crops. Over the long term, however, such practices may not be wise, as they can wear out the soil, increase erosion, and foster the growth of diseases and pests.

The method of farming hilly lands is very different. In this case, erosion is the farmer's greatest enemy. Sloping land cannot be cropped every year, so it is best to use a system that routinely rotates crops with sod pasture. Soil preparation machinery must be suited to deal with thick sod.

The garden is a special case for soil preparation because many kinds of vegetables with different growing habits are produced in a small area of land. Since the land is worked very frequently, it is usually not possible to set aside areas for sod rotation. Gardens thus need large amounts of organic matter added yearly to keep the soil from becoming exhausted. The size of a garden should be no larger than one's supply of manure or compost can cover.

SOIL PREPARATION OF FERTILE LOWLANDS

This method of soil preparation is used on large level fields where erosion is at a minimum. The main crops are corn, wheat, rice, millet, sorghum, and soybeans. Comparative advantages and disadvantages include the following:

*** Large tractors are used to prepare the ground for planting in the following steps:**

- Commercial fertilizer and lime are spread by truck or tractor-drawn wagon. Fertilizer may be applied by planters.

- Land is chisel-plowed six to eight inches deep.

- Land is then smoothed out by disk harrow or spike tooth harrow after plowing (with very large tractors, it is possible to plow and smooth in one operation using a large disk harrow).

- Right before planting, a second smoothing operation using disk or spike tooth harrow should be undertaken if needed.

- The seeds of row crops such as corn are planted on level ground if irrigation is not used; on ridges if irrigation is used; or on the side of ridges if land is salty. Row crops are planted with row crop planters. Small grains such as wheat are

planted with a grain drill.

*** Labor requirements are low, which is an advantage when labor costs are high.**

*** Energy use is very high.**

*** Maintenance requirements for machinery are extremely high.**

*** The cost of the equipment is very high, but on land that gives good yearly yields and where labor costs are high, this type of farming will return more per acre than any other, particularly if many acres are planted and machinery is used to the fullest extent. This system can work if one person has many acres of level land to cultivate, particularly if crop yields can be assured through irrigation. However, this system will not work if existing loan interest rates for machinery are high or if grain prices fluctuate widely.**

*** If herbicides are used, one or more of the soil preparation steps may be left out. Fields may not need to be plowed or harrowed, for example. No-till planters can plant directly in unplowed land by opening up a furrow with the disks and spraying the middle to kill weeds. However, every few years the land must be plowed to bury excessive crop residues that can clog planters or harbor plant diseases.**

SOIL PREPARATION ON ERODIBLE UPLAND SOILS

These soils need a sod cover crop for at least half the year to keep erosion to a minimum and rebuild soil structure. The land on the farm is divided into two, three, or four segments with one portion cultivated each year. Table 2 below shows the relationships between the slope of a field and the ideal rotation periods for planting. These are averages for all soil types. Soils with a thin topsoil, particularly when the subsoil is clay, should be cultivated less often. This type of agriculture is highly suited for small tractors (20 to 40 horsepower) or for animal-drawn equipment.

Table 2. Number of Times During a Four-Year Period That Land May Be Cultivated

Percent Slope(*)	Allowable	Preferred

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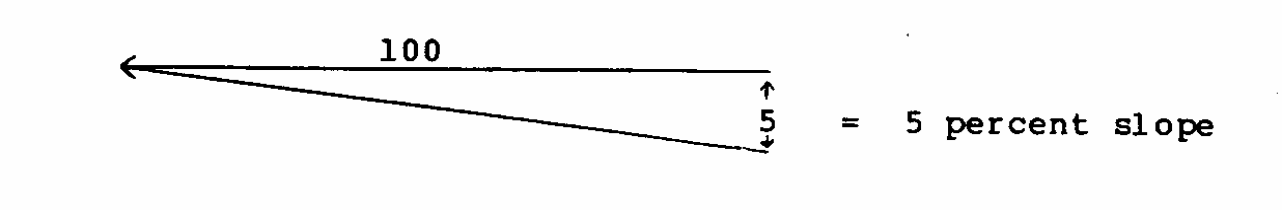

0 4 3
0-2 3 2
2-6 2 1
6-10 1 0
Over 10 0 0

(*) Percent slope is found by measuring the number of feet (or meters) the land falls every 100 feet (or meters).

The method of soil preparation is as follows:

*** Apply lime if needed.**

*** If the cover crop is thick and viney, turn land with a moldboard plow with a colter. In the second and subsequent years of cropping, implements other than the moldboard plow may be more efficient and better for the soil. These include the chisel plow, depending on crop sequence and weeding techniques.**

*** Smooth soil with harrow immediately after plowing.**

*** Wait approximately three to four weeks for cover crop to decompose.**

*** Smooth with disk or spike tooth harrow with drag if needed before planting.**

*** Plant seed with a row crop planter or grain drill in rows that run across the slope of the land. This will help prevent the topsoil from being washed away. Except where rainfall is always plentiful during the growing season, it is best to plant row crops such as corn in a furrow two to four inches (five to ten cm deep). This will provide moister soil for germination; make cultivation easier (soil can be pushed into furrow to kill weeds); and, in the case of heavy downpours, tend to stop erosion. In areas of heavy rainfall, apply fertilizer at time of planting.**

The amount of labor needed to cultivate a particular area of sloping land is higher than on the level lowland farm because small equipment is used. However, since the land is only cultivated a portion of the time, the total amount of labor needed for the whole farm on the average can be low. If draft animals are used, the labor requirement is higher; it takes longer to cultivate the same amount of land with animals than with tractors, and the animals must be fed and housed.

Energy use is moderate since smaller equipment is used. Moreover, land in the sod part of the rotation will require little energy use, and if legumes are grown, the nitrogen fertilizer cost will be lower. The maintenance requirements of the machinery used will be proportional to its size. There will also be a periodic upkeep required on any fencing used.

The cost of such a system is lower than that for the lowland

farming technique since smaller equipment is used. However, because fencing and animals will have to be purchased in the beginning, initial costs can be high. Also, a mower might be necessary if the stock cannot control all the weeds in the pasture--weed control during the sod or pasture phase of rotation becomes very important during the periods when field crops are cultivated. In the long run, the cost per acre of land will be lower and the animals will provide additional income that is often steadier than the marketing of grain.

The main advantage of this system is that the sod crop does most of the soil preparation itself. The roots "plow" and "subsoil" the ground and legumes capture nitrogen from the atmosphere and help save on fertilizer expense. The root action helps distribute organic matter and nutrients to a great depth in the soil, thus fostering the root growth of the cultivated crop that follows. While the field is in a sod crop, erosion will be virtually halted and when the soil is exposed during the cropping year it will be less likely to erode because of its higher organic matter content and water-holding ability. Contour bands of sod between row crops will help catch eroding soil on steep hillsides.

Many weeds that hinder cultivation in continually cropped fields are smothered out during the sod portion of the rotation. Broad leaf weeds are hardest hit. Either the weed seed is killed before germination or it is consumed by livestock before it can reseed.

The only disadvantage to this system is in the time lost in the spring during the month-long decomposition period. Also, plowing-under a sod crop may be somewhat more difficult than plowing bare ground.

In general, it is best to use a moldboard plow to turn sod. However, it may be advantageous on large acreage to use the no-till practice for as many years as possible. With this practice, a herbicide is used to kill the foliage of the sod. Seed is then planted into narrow furrows opened by disks. Other herbicides are used to kill subsequent sod and weed growth.

SOIL PREPARATION IN GARDENS

This third category of farming is confined largely to small areas of intensively cultivated land where large amounts of organic material are added regularly. The main crops produced are vegetables. Often, many different kinds of vegetables are produced within the garden and many successive plantings and harvestings take place during the growing season.

The two main methods of soil preparation are clear cultivation and mulch gardening. In deciding which techniques to use, the gardener should consider the soil structure, the amount of time available for tending the garden, and what type of tools and machinery are available.

A thick layer of mulch:

*** shades out weeds,**
*** helps soil retain moisture,**
*** prevents erosion,**
*** protects soil from traffic compaction,**
*** keeps soil from splashing on plants, and**
*** reduces the amount of equipment required, but,**
*** on the other hand, may possibly harbor insect pests and disease.**

Clear cultivation:

*** allows use of mechanical tillage**
*** works well against grass-type weeds**
*** works well on large-scale cultivating.**

In clear cultivation, a small tractor, animal-drawn cultivator, power tiller, or hoe is used to keep the areas between the vegetable rows clear of weeds. The soil in these areas, which usually becomes hard due to heavy traffic, is loosened in the same process. In mulch gardening, thick layers of straw, leaves, bark, plastic film, or newspaper are placed between the rows to shade out most weeds. The soil under the covering remains loose and retains moisture. This method makes cultivating machinery impractical, but requires hand weeding to remove any pest plants that may break through the mulch.

Both clear cultivation and mulch gardening require the addition of large amounts of manure, compost, and/or fertilizer to the soil regularly; use as much manure as possible, up to 10 tons per

acre (2,000 kg per hectare). The simplest method is to spread fresh barn manure over the garden at the end of the growing season and work this into the soil immediately by plowing it under, mixing it with a tiller, or spading the ground deeply with a fork-type tool. By planting time, the manure will have decomposed enough so as not to harm the growing crop. Note that in tropical areas of relatively high year-round temperature and long seasons of very heavy rains, it may be better to spread aged manure over the garden just before planting. Organic matter decays completely very quickly in the tropics, and humus and nutrients may be washed away by the rains before they can be of use to the crop.

If tillage is to be employed, space the rows far enough apart to accommodate the kind of equipment used. Three to four-foot spacing (1-1.2 meters) for an animal-drawn cultivator and three-foot spacing (1 meter) for a power tiller are recommended. Smaller-spaced rows may be used with hand hoeing.

When mulch is used, the vegetables may be grown in beds approximately four feet wide with traffic paths in between. All walking is done on the paths so as not to compact the soil in the beds. Topsoil may also be dug from the paths and placed on the beds to increase rooting depth.

Although gardens are extremely labor intensive, cultivating time may be reduced by the use of machinery. Manure spreading is the hardest job. Cultivating is much easier, however, if the manure or compost is added in sufficient quantities, as the organic

matter will make the soil much easier to work. The efficiency of a garden can be greatly increased by irrigating during dry periods. This will ensure profitable yields in times when drought might have made all the work a waste of time. Row plantings may be irrigated simply by allowing water to flow between the rows. Irrigating mulched beds may require more care and possibly special equipment such as drip irrigation systems. However, the mulch helps retain soil moisture and so less frequent irrigation is necessary.

The cost of a garden should be kept as low as possible. When a garden is combined with a rotational system that includes livestock, a steady supply of manure is available. This virtually eliminates fertilizer costs. A heavily manured garden will produce abundantly in a small area of space. A small garden will not require much machinery, keeping costs way down.

Maintenance requirements should also be low. All machinery should be lubricated properly and the surfaces of iron, steel, and leather items oiled regularly. Hoes should be kept sharp for fine weeding.

The best way to ensure a large supply of animal manure is to keep livestock in a barn, corral, or other enclosure at night. Bedding straw retains urine and keeps manure drier. This system works exceptionally well with sheep or goats.

LAND USE SURVEY

All farmers should make a land use survey of their farms. Many farms are composed of both good and poor land, in one field or in several distinct fields. Each field must be rated according to slope, size, and soil type. These factors will determine how often and what type of crops are to be grown in each field.

Many acres-along narrow rivers have fertile level fields next to the river that can be cultivated every year. As one moves away from the river, a point is reached where the slope becomes steeper and the land rises toward a hill. These hillsides should be used for livestock grazing and cultivated only at intervals.

Each of the three major types of agriculture can show up on a farm. Farmers will choose the type of agriculture and soil preparation needed for each part of their farm.

SOIL PREPARATION EQUIPMENT

Soil preparation technology has developed as people have built bigger and bigger machinery. However, the greatest mistake a farmer can make is to buy machinery that is larger than the job that needs to be done.

Most gardens should still be worked by hand. It is the lack of manure and compost that makes the soil hard and leads farmers to think they need more equipment to work it. Mixed livestock and crop farming on sloping land needs no more than a small tractor or draft animals. Only the huge farms and the most fertile, level land can economically use today's large tractors.

The system of rotational agriculture was developed before the invention of the tractor and commercial fertilizer. It is a system in which plants and animals do most of the work of preparing the soil for the production of crops. Hence, it is well suited to farmers who have little money to spend and whose land will not produce the grain yields obtained by prime bottom land farms where farm technology is at its peak.

Rotational livestock grazing systems require less equipment than cropping. The more land grazed, the more manure is available for the portion of land that is cropped.

REPLACEMENT OF NUTRIENTS

Growing plants absorb nutrients from the soil. These nutrients must be replaced, or the soil will lose its ability to support healthy plant life. The major nutrients that have to be replaced regularly are nitrogen, phosphorus, potassium, and calcium. All can be bought as commercial fertilizers, but they are also found in all kinds of vegetable matter and animal waste products (see Table 3). Many of these resources can be obtained locally.

The best way to use plant wastes is to compost them. Composting breaks down fibrous vegetable matter and makes it easier to mix with the soil. Bacteria and fungi digest large vegetable parts, turning the material into a nutrient-rich fertilizer. Compost piles are made by alternating layers of plant wastes, manure, and a calcium source such as limestone or ash. If the pile is kept

moist, the vegetable matter will be combined with manure and calcium to form humus, a perfect source of plant nutrients.

Raw manure can be spread directly onto the field, but during hot, wet weather it should be worked quickly into the ground for sanitary reasons. Manure has an unpleasant odor but if properly handled, it should not smell strong. It also contains large amounts of nitrogen which will be lost to the atmosphere if not worked quickly into the soil.

Table 3. Nutrients Found in Vegetable and Animal Wastes

Source	Nutrient Supplied
Stable manure	Nitrogen, phosphorus, potassium, calcium
Human waste	Nitrogen, phosphorus, potassium, calcium
Waste vegetable parts	Nitrogen, phosphorus, potassium, calcium
Leaves	Phosphorus, potassium, calcium
Wood ashes	Potassium, calcium

Ground bones Calcium, phosphorus

Ground shells Calcium

Manure and fertilizer need to be spread evenly over a field. If allowed to remain in piles, it can burn plants, stunting their growth. It may also produce growth that is too rapid, causing lack of buds, or lodging, in grain and vegetable plants that are all vine. Lime should also be spread evenly to be of greatest value.

III. FUTURE OF SOIL PREPARATION TECHNOLOGY

In the future, the mechanical processes used in agriculture will increasingly to be replaced by biological methods. Over the past 10 years, the cost of machinery and replacement parts, fuel, fertilizers, and other agricultural chemicals has doubled, while grain and livestock prices have remained stationary. Thus, there is an ever-increasing need for farmers to manufacture their own soil inputs. While potassium and phosphorus may have to be purchased or secured off the farm, the most important nutrient, nitrogen, can be produced by the use of soil-saving legumes and manures.

More research is needed to develop new varieties of legumes for crop rotation or for companion cropping. An ideal legume would

grow vigorously for a few months before the grain crop is planted. Then the legume would become dormant and act like a mulch while the grain crop is growing, only to revive growth after the grain is harvested. Such a plant does not yet exist, but legumes should be included in soil-building programs. Properly suited legumes must be introduced to areas where their seed is difficult to purchase. Legumes are also important to soil conservation efforts. Erosion is a world-wide problem, and land too steep for continuous cropping should be placed in pasture. Legumes such as alfalfa provide excellent pasture while they enrich the soil.

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