Article

How Should Christians Promote Sustainable Agriculture in Agrarian Systems? A Normative Evaluation

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Empowerment of the very poor to produce sufficient, healthful food for personal consumption and trade is critical to the reduction of chronic hunger and poverty. To produce food in a sustainable way that does not jeopardize environmental quality is important, allowing Christians to fulfill the Gen. 2:15 command "to serve and protect" creation. Application of sustainable agricultural practices in the agrarian systems of small farmers in poorer countries, as they are practiced in industrialized systems, implies the adoption of an inherently unsustainable industrialized process. Industrialized systems could harm ecological processes and damage community structures in poorer countries, jeopardizing their future production capacity. The purpose of this article is to distinguish principles of sustainable agriculture from specific practices in order to advance agricultural development that is economically, socially, and environmentally sound. Biblical norms justify the principles of sustainable agriculture, and these principles can inform place-based practices that have the potential to both honor God and sustain creation. Better agricultural development will result from an extended dialogue between industrialized and agrarian producers, each striving to adapt practices that achieve the principles of sustainable agriculture.

Global hunger and poverty are difficult, intertwined, and multifaceted problems that have persisted for centuries. People who do not receive an adequate diet are much more likely to suffer from a range of ailments and exhibit significantly shorter life expectancy. Chronic hunger, as distinguished from acute starvation, develops gradually as a result of a person receiving slightly insufficient calories and/or improper nutritional balance over an extended period of time. Children with weakened immune systems are vulnerable to a plethora of parasites and waterborne diseases, possibly leading to dehydration and death. While exact numbers are unclear, experts estimate that 800 million people suffer from chronic hunger globally.[1] Malnutrition

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disproportionately hurts children. The World Health Organization estimated that 112 million children, 26% of whom are under age five in developing countries, were underweight.[2] In fact, chronic hunger may kill as many as thirty-four thousand children under age five daily, or twelve million children per year.[3]

Hunger is inextricably linked with poverty, perpetuating the so-called "poverty trap." Agrarian (subsistence) farmers often lack the financial resources to invest in improved seeds, chemical fertilizers, pesticides, and water management systems. Of the 6.2 billion people inhabiting Earth in 2005, the World Bank estimates that 1.4 billion were living in extreme poverty, defined as having an income of $1.25 per day or less; 852 million of these were undernourished.[4] With recent increases in food prices, they further estimate that one billion people will go hungry while another two billion will be malnourished.[5]

Such statistics have long inspired spirited efforts by the faith community to increase food production capacity both for consumption and for sale in the market. On at least nine occasions, the biblical narrative calls us to "love your neighbor as yourselves."[6] The Bible makes clear that "the poor you will always have with you" (Matt. 26:11; Mark 14:7), and yet we are called to help them by giving of our possessions while seeking our true treasure in heaven (Matt. 19:21; Mark 10:21). We live in a time when the goods and services of global ecosystems are shared (including the air we breathe) or traded in the context of a global economy, making all of the earth's inhabitants our neighbors. To love our neighbors we must also assure access to, or at least not impede access to, daily water and bread just as Jesus did when he fed the five thousand (Matt. 14:13; Luke 9:10).

Sustainable help to neighbors, however, requires a careful response. We should not create a state of welfare or cause unintended harm.[7] Advocacy of appropriate principles and practices should do no harm to people or to the environment on which they depend for food and water. One approach of significant merit is that of the Christian Reformed World Relief Committee, which seeks to empower impoverished communities to be self-sustaining. It provides holistic support for their long-term physical and spiritual development by facilitating community transformation.[8] Knowing what specific actions to take, however, is not a simple matter. Westerners involved in development work usually have a natural tendency to use those systems with which they are familiar and which brought them a measure of success. Thus, it might seem very reasonable to empower farmers in developing countries by having them forego their agrarian practices and instead adopt the industrialized agricultural practices to which we are accustomed. This, however, may not be a wise plan.

One objective of this article is to provide a clear affirmation of the principles of sustainable agriculture (SA) while also illustrating that deployment of the SA practices used in the industrialized food production process of developed countries could, in fact, be harmful to people and their environment in poorer countries with high populations of small farmers. A second objective is to suggest that people in industrialized countries may gain insights about how to produce food in a more agroecologically sound way by learning from agrarian practices.

Steven Hall presents SA as a redemptive and restorative process of food production consistent with the biblical vision of sustainability reflected in creation care and the command to love God and our neighbor.[9] While the principle goals of SA are biblically supported and appropriate to maintain food production capacity, the SA practices associated with industrial agriculture make less sense when applied in the context of very poor, small shareholder farmers in poor countries. The sort of efficiency gained by industrial agriculture is not the efficiency primarily needed by small farmers. More specifically, industrialized efficiency rewards the most calories produced per unit of labor, rather than the quality calories produced per unit of water, nitrogen, or energy. Small, poor farmers lack access to costly technologies such as pesticide application, irrigation systems, and hybrid seeds because they are also frequently among the world's impoverished; however, they often have access to human labor. Secondly, the poor lack the infrastructure required to address soil erosion, water quality, and health issues that eventually arise from the industrialized food system and associated diet. More "appropriate technologies,"[10] a different set of SA practices consistent with SA principles, are required in support of poor, small shareholder farmers.

Sustainable Agricultural Practices Improve, But Do Not Fix, the Industrialized System

It might seem that people in industrialized countries have solved the food production challenge. We do produce a lot of food. One way to empower less fortunate global neighbors might be to share the knowledge and technology we used to increase food production capacity. Industrialized food production systems are incredibly efficient in producing large quantities of food with a minimum of labor. By integrating the use of tractors, improved genetics, fertilizers, and pesticides in a complex monoculture system, one US farmer can produce enough food annually to feed 140 people.[11]

However, serious tradeoffs challenge the sustainability of this industrialized food system. In a *Science* article, Peter Raven lists a number of global concerns: we treat agricultural lands with three million metric tons of pesticides per year; we fix more chemical nitrogen fertilizer, using natural gas via the Haber-Bosch process, than all natural processes combined; we have already lost 20% of the world's topsoil; 20% of agricultural land is now so degraded that it is no longer able to support food production; and species extinctions are three orders of magnitude higher than the geologic baseline.[12] Most of the grain that is produced is fed to livestock or distilled to produce ethanol for automobiles. The global grain supply is now consistently below demand as evidenced by the high commodity prices and "rice riots" of recent years. Even though industrialized agriculture can produce some impressive food yields and is labor efficient, costs to the environment and the persistence of hunger suggest that this food production system is unsustainable.[13]

Most farmers using industrialized systems are aware of these environmental issues, but they are trapped in the larger food system and must do what is required to stay in business. Farmers adopt a technology that balances the environmental protection mandated by law and the Farm Bill, against the maintenance of high-yield levels required by the commercial market to stay solvent. Farm Bill and market constraints require farmers to increase fertilizer use, install irrigation systems or drainage tile, and utilize pesticides to maintain high-yield levels. The number of farms fell dramatically from its peak of nearly seven million in 1935 to 1.9 million farms in 1997; eight percent of these very large family or nonfamily farms account for 68% of production today.[14] Whereas more than one-half of Americans farmed in the 1940s, fewer than two percent of Americans farm for a living today, and only seventeen percent of Americans now live in rural areas.[15] Therefore, while economically sustainable, industrialized food production systems are environmentally and socially unsustainable.

Sustainable Agriculture Is …

Sustainable agriculture represents a number of approaches or techniques developed to improve these economic, environmental, and social problems. The US Department of Agriculture defines SA as

> an integrated system of plant and animal production practices having a site-specific application that will, over the long term: satisfy human food and fiber needs, enhance environmental quality … and enhance the quality of life for farmers and society as a whole.[16]

The breadth of this definition is helpful at one level because it suggests that economic, environmental, and social concerns must be considered together, but it provides little specific insight into what needs to change. Consequently, perceptions of what SA is vary widely when viewed from the perspective of farmers, economists, environmentalists, or rural sociologists. To some, SA represents small changes to an industrial food production system intended to reduce environmental impact while still protecting profitability. For others, SA represents a radically different concept of food production, namely, an agroecological system typified by highly integrated polycultures.

The mainstream perspective of SA in the USA is to make small modifications to the industrialized food production system aimed at improving the triple bottom line by optimizing economic profit, minimizing environmental damage, and maintaining social acceptance. New practices minimize soil erosion, increase fertilizer efficiency, reduce fertilizer runoff, increase irrigation water use efficiency, and reduce pesticide exposure. Economic calculators, or weed, insect, and disease fact sheets, and numerous other decision tools, help farmers select practices that protect economic health while minimizing environmental damage.[17] For example, while

Integrated Pest Management (IPM) does not abrogate pesticide use, it does not account for important externalized costs, real and indirect costs (e.g., healthcare, reintroduction of biodiversity) that are not accounted for in the purchase price of a product. The voluntary use of IPM has reduced pesticide use by encouraging farmers not to apply pesticides unless it is necessary to protect the real economic potential of a crop field. A second example is the adoption of no-till or minimum tillage to reduce soil erosion. Seed quality, farm equipment, and pesticide options have improved sufficiently for farmers to now achieve comparable yields, or at least minimal losses, when adopting a no-till system. These SA practices which dominate in the US food production system represent gradual improvements of a problematic system.

Another competing perspective of SA is agroecology. An "agroecological" approach encourages the application of ecological principles in agricultural environments. Stephen Gliessman refers to agroecology as the integration of the broader ecology into the agricultural process to create an agroecosystem.[18] Agroecological producers actively promote the use of natural predators or integrated cropping systems and polyculture as a replacement for pesticides and chemical fertilizers. Agroecological operations tend to be small in size and rely heavily on human labor. Gliessman argues that agricultural systems can no longer be viewed as strictly production activities driven primarily by economic pressures. They should consider all inputs and outputs with the surrounding environment and community. The agroecological approach represents a significant paradigm shift from the industrialized systems that most of us are accustomed to. Arguably, such a shift is necessary to achieve true sustainability.

While it is generally agreed that present industrial agriculture is unsustainable, there are very different opinions about what SA should look like within developed countries. For example, the advice of the International Assessment of Agricultural Knowledge, Science and Technology for Development,[19] which encouraged agroecological practices, was largely rejected several years ago, possibly because it either represented a significant shift from the current industrialized approach or challenged the potential to market high-value industrialized technologies. If SA means broadly different things to different people in developed countries, it should not be a surprise that confusion exists around the question of what sorts of agricultural practices should be exported to people in developing societies. Therefore, careful discrimination between *SA principles* and biblical norms that support those principles, and the *SA practices* required to instantiate the principles, are necessary. We need a guide to help us identify which SA practices to advocate among small agrarian farmers in poorer countries, as well as among stakeholders relying on the industrialized system.

Side Effects of the Industrial Food Production System Conflict with Creation Care Norms

As responsible stewards of God's creation, we should promote production systems that create a minimal disturbance in order to protect productivity and resilience. At least four biblical norms inform the Christian worldview of crop production practice and promote good environmental stewardship. First, *God claims ownership over all elements of creation, so as humans we should seek to protect the diversity that God created.* The Old Testament narrative claims that everything in heaven and on Earth belongs to God (Deut. 10:14, 1 Chron. 29:11, Job 41:11, and Ps. 24:1) and that God cares for all the diversity he created (Job 38–40). Therefore, as garden caretakers, we are responsible to promote the biodiversity that produces resilience.

World Resources Institute reports that agroecosystems cover more than one-quarter of the global land area, with much of the remainder unsuitable for food production.[20] Industrialized production systems mainly use monocultures to optimize productivity in a labor-efficient manner. Monocultures (fields are planted with one crop type and individual plants of identical genetic composition) are maintained with the use of pesticides and tillage to prevent weeds from competing for resources. While the use of some land resources for food production is reasonable, conversion of virtually all native ecosystems, such as tall-grass prairies to corn and soybean monocultures, seems excessive. These behaviors signal a problem with our stewardship. We have replaced much of God's created diversity with monocultures in order to produce feed for livestock and ethanol for automobiles. A paradigm shift to an agroecosystem approach, on the other hand, employs biodiversity to produce food and to protect ecosystem resilience. David Kline argues that to stop and move the chipping sparrow nest when plowing a field in the spring not only preserves the life of one of God's creatures, but it also provides a natural way to control insect crop pests, owing to the large appetite of these insectivorous little birds.[21] It should be intuitive that one aspect of the goodness of God's creation is that all created creatures, not only humans, have a role in the natural process of agroecosystems.

Second, *humans and natural systems require a rest period.* "For six years you are to sow your fields and harvest the crops, but during the seventh year let the land lie unplowed and unused" (Exod. 23:10–11a). A similar command in Lev. 25:3–4 is accompanied by God's promise, "If you follow my decrees and are careful to obey my commands, I will send you rain in its season, and the ground will yield its crops and the trees of the field their fruit" (Lev. 26:3–4), and "you will eat all the food you want and live in safety in your land" (Lev. 26:5b).

Agricultural land seldom receives a fallow period these days with current agricultural practices. That was not always the case. In the pursuit of maximum profits, every year crops are planted in each field, and even in what were once fencerows. Some fields are planted with the same crop type every year, mostly as continuous corn production which prevents the sort of rest associated with crop rotation. One way of adhering to biblical instruction might be to provide agricultural land "rest" by building a fallow period into a crop rotation, by the use of "green manures" in which biomass is returned to the soil as a form of carbon sequestration, or by the adoption of polyculture that minimizes soil exposure. "Rested" soils can recover and regenerate, regaining native fertility and reversing degradation.

Third, *we are commanded "to serve and protect" God's creation.* A production system that pollutes the land conflicts with the "goodness" of the created order (Genesis 1) and represents an imbalance of the dual command "to serve and protect" (Gen. 2:15).

As a consequence of the heavy use of fertilizers, pesticides, and irrigation water required to maintain productivity in monocultures, it is clear that we have extensively polluted the soil and our fresh water. The substantial sediment load in streams following rainfalls stems largely from agricultural fields. Negatively charged soil particles also carry a load of nutrients and chemicals into the watershed where they drive an eutrophication process unhealthy for aquatic systems. Topsoil loss contributes to lower soil fertility, compensated for by higher fertilizer application, which further exacerbates the degradative cycle. Poor freshwater and coastal ecosystem health is significantly rooted in the food production process and represents one of the biggest threats to global health.[22]

Fourth, *God sustains, holds together, and has ultimate power over creation.* The psalmist wrote that God cares for the land, waters it, and enriches it abundantly in order to provide grain for people (Ps. 65:9). The created order is held together by God (Col. 1:17), who also retains the ability to shut up the heavens, producing drought, or unleashing locusts which eat crops (2 Chron. 7:13). God has declared this creation "good" (Genesis 1) and actively maintains it through God-ordained natural systems.

Much of industrial agricultural practice relies on a reductionist approach in which individual components of an agroecosystem are controlled or managed without regard to the overall health of the system. For example, the availability of nitrogen for annual crop plants is maximized by applying chemical fertilizers such as anhydrous ammonia or urea, without regard to fossil fuel cost, carbon footprints, downstream effects, soil microflora health, or soil pH levels. In contrast, this norm argues for a holistic system approach in which biodiversity provides insect control support, nitrogen-fixing crops are either rotated or grown in polyculture to provide naturally produced nitrogen, and disease and insect life cycles are broken. A properly constructed agroecosystem, one modeled after the holistic principles of ecology ordained from the beginning of creation, has great potential to provide sustainable food resources and ecological services. A paradigm shift toward agroecosystems, structured to complement natural systems rather than fighting them, could afford a sustainable supply of the variety of goods and services required by all beings.

Biblical Norms Support Principles of Sustainable Agriculture But Not Specific Practices

In his article, "Toward a Theology of Sustainable Agriculture," Steven Hall provides a broad biblical framework of SA with three foci: the environment, economy, and community.[23] The first biblical theme supporting the environmental component of sustainability is found in Genesis 1, which proclaims the goodness of God's creation and gives humans the responsibility to keep and preserve the land, allowing it to recover after use (Gen. 2:15; Exod. 23:11; and Lev. 25:4–7). Secondly, Hall argues that money-valued resources, such as land (Exod. 12:44) and the food that can be produced on it, can represent appropriate economic sustainability rather than the love of money (1 Tim. 6:10). Use of land or food production systems that rely upon unsustainable practices in the quest of an egregious lifestyle would reflect an inappropriate use of money. Third, multiple Old and New Testament passages illustrate that people who are concerned about the well-being of their neighbors as much as themselves encourage the development of healthy communities (Lev. 19:18; Matt. 19:19, 22:39; Mark 12:31, 12:33; Luke 10:27; Rom. 13:9; Gal. 5:14; James 2:8).

The consolidation of small family farms into large agricultural operations in recent decades has virtually created modern ghost towns in many midwestern states, representing a loss of community. A persistent perception of farmers as unrefined, backward, or uneducated people, by those who have little sense of where their food comes from or what it takes to produce that food, reflects a lost sense of community. Yet farming and nonfarming people are inherently interconnected via the environment, economy, and communities at local and global levels. All people, whether they realize it or not, depend on healthy ecosystems to provide goods such as food and fiber, and services such as filtered water and clean air—resources that we take for granted. An alignment of sustainable agricultural systems with basic food needs, while maintaining healthy ecosystems capable of providing the goods and services required for healthy and prosperous communities, should be a primary goal of political and faith communities.

I consider Hall's theological principles of SA to be wholly consistent with the biblical norms commonly associated with creation care. But in order for Christians to be responsible actors in the food system and to be able to advocate for appropriate food production practices, these principles need to be connected with place-appropriate practices. In the following sections, SA practices of industrialized food systems will be compared with the practices and the appropriateness of agrarian systems, with reference to each of the SA principles.

Reduce Soil Erosion

The top eight inches of soil, the "skin of the earth" on which life depends, according to a recent National Geographic article, is one of humankind's most limiting nonrenewable resources.[24] Once lost, the genesis of new soil requires millennia. Wind and water erosion remain a major concern in food production. Because healthy soils are required to provide the water, nutrients, and oxygen that plants need to produce a maximum food yield, soil erosion represents a significant threat to food security. Industrialized agriculture is extremely hard on soil.

> The average corn farmer who never rotates crops loses around twenty tons of soil per acre per year with conventionally tilled corn. This is the equivalent of 2.3 bushels of soil lost per bushel of corn harvested.[25]

Crop plants grown in rows during three months of a calendar year provide little resistance to the erosive power of water flowing through a field. Consequently, 20% of the soil has already been lost, resulting in siltation in rivers and reservoirs, the creation of a dead zone in the Gulf of Mexico, and the red-brown color of rivers that should actually run a clear, amber color following a rain.

The good news is that farmers using industrialized systems continue to adopt SA practices such as no-till and minimum tillage, construction of terraces, and maintenance of grassy waterways that have reduced soil erosion by 40%. The bad news is that erosion still exceeds the soil genesis rate by two to one. As long as row crop systems persist with monoculture crops such as corn and soybeans, it will be hard to bring the rate of soil loss into equilibrium with soil genesis.

Low soil quality is also a problem for growers in agrarian systems, yet they lack the financial resources to augment degraded soils with fertilizer and irrigation. Agrarian or subsistence producers may have other options. Practices which incorporate compost, instead of burning crop residue after harvest, will reduce erosion by providing a barrier to water flow and will enhance soil quality by adding organic carbon. Small shareholder farmers with animals may have the opportunity to incorporate crop residues, add soil nutrients as manure, and rotate a greater number of crops. Use of perennial crops preserves soil by maintaining year-round root systems that effectively hold soil in place. Finally, communities with greater labor availability may use a polyculture system, utilizing a menagerie of perennial (fruit trees) and annual crops positioned to optimize light, water, and nitrogen cycling, while holding soil in place. The goal of each of these practices is consistent with the SA principle of conserving soil. The practices of each system to achieve this goal differ widely, reflecting not merely a difference in economic circumstances but also a fundamental difference in the underlying paradigms of industrial and agrarian agriculture.

Reduce Pesticide Use

In Gen. 3:17–19, we read,

> Cursed is the ground because of you;
>   through painful toil you will eat of it
>   all the days of your life.
> It will produce thorns and thistles for you
>   and you will eat the plants of the field.
> By the sweat of your brow
>   you will eat your food
> until you return to the ground,
>   since from it you were taken;
> for dust you are
>   and to dust you will return.

Industrial agriculture relies primarily upon pesticides to control weeds that compete for sunlight, water, and nutrients, or to control the insects and diseases that consume crops. Pesticide control has effectively protected crops, providing large yields. While the benefit of greater productivity and lower food prices are obvious, there are negative tradeoffs from pesticide use. First, pests eventually develop resistance to pesticides, requiring higher doses or new active ingredients. Just fifteen years after introducing crops engineered to be resistant to Roundup™ herbicide, weeds are already becoming resistant.[26] Second, many pesticides kill unintended targets; most insecticides kill both crop pests and beneficial insect predators. Third, pesticides are responsible for the numerous poisonings and chronic illnesses of agricultural workers.[27] Effective pest control will remain a challenge as predicted by the "sweat of the brow" curse that followed the Fall. While the use of pesticides allows people in industrialized systems to avoid some of the work described in this curse, its benefits are accompanied by a number of challenges.

While pest control is critical to achieving high and reliable food yields, SA practices of industrialized systems make less sense in agrarian systems. Pesticides are expensive, they are not always effective, some are toxic to humans, and pests become resistant. The lowest cost pesticides, no longer protected by patents, are often used by the small farmers. These are frequently older broad-spectrum compounds which are more toxic to humans and the environment.[28] In Carchi, Ecuador, adoption of these pesticides doubled potato yields initially, but pests soon developed resistance. Carchi farmers responded by applying higher concentrations more frequently in order to maintain high yields. A community health concern developed when some Carchi farmers, who were applying pesticides without protective clothing or sound hygienic practices, experienced disabilities and premature deaths, along with their family members. "Ecosalud" developed as a successful movement of farm widows who promoted natural control methods coupled to safer pesticide use (only when it was absolutely necessary).

Fostering biodiversity can reduce, and in some cases replace, the requirement for pesticides, even in surprising ways. Consider, for example, the Amish farmer who preserved the nest of his insectivorous chipping sparrow.[29] While modern insecticides are more selective than their predecessors, they often kill beneficial insects, too. High populations of ladybugs, lacewings, and wasps help to keep plant pests in check. Crop polyculture provides both spatial and temporal diversity that disrupts the life cycles of insect and fungal pests. While there may be appropriate times and places to use pesticides, preferential adoption of agroecological approaches to disrupt pest life cycles, to encourage prognosticators of pests, or to use native crops with natural defense mechanisms, should be a first line of defense.

Because IPM focuses on economic sustainability, it may underestimate social and environmental costs as reported in the Carchi case study. Use of highly diversified polyculture systems and human labor in agrarian environments can mitigate some pesticide use by engaging a variety of ecological advantages.

Optimize Water- and Fertilizer-Use Efficiency

Water and nitrogen fertilizer are critical to optimizing yields. 2.3 billion of the earth's 6.4 billion inhabitants (41% of the human population) lack access to adequate water.[30] Nearly one-fifth of global food production lands rely upon irrigation water to maintain high yields. While water is critical to food production capacity, optimizing water use efficiency (WUE, the quantity of food produced per unit of water) is an important metric. SA techniques of industrialized systems are focused on optimizing WUE by transitioning from gravity or high-pressure sprinkler systems that lose a large percentage of water to evaporation, to low-pressure systems. Low-pressure systems are more efficient in delivering water, but are expensive. Soil erosion is indirectly related to the problem of insufficient water because eroded soils store less water and nutrients with which to support plant growth, driving the need for more irrigation.

Crop plants in agrarian systems also require large volumes of water, but farmers in these systems cannot access irrigation technology even if water were available. Jeffrey Sachs advocates that wealthy industrialized nations ante up to the UN in support of large infrastructure development such as dams and irrigation canals to supply water for irrigation.[31] On the other hand, Paul Polak of International Development Enterprises advocates empowering small shareholder farmers with a variety of low-cost solutions such as treadle pumps and trickle irrigation systems.[32] For \$25–\$50, the poorest of farmers with access to fifty gallons of water per day can support a vegetable garden. In Cambodia, groups such as Resource Development International develop, produce, and sell novel home use water filters for consumption and merry-go-round water pumping systems to enable people to access irrigation water.[33] Access to even a small amount of water using such technology can enable a family to grow enough vitamin-rich vegetables to augment a rice-based diet and reduce vulnerability to water-borne pathogens. While large, expensive infrastructure and technology might have its place, simple approaches can often replace the need for expensive technological solutions.

A number of mineral nutrients (the largest quantity of which is nitrogen) are required as well as water to optimize crop yield. Cereal grains commonly produce ~40% yield increases when nitrogen fertilizer is applied. In the industrial paradigm, chemical fertilizers are the main way nitrogen is delivered to corn, wheat, and rice. Nitrogen fertilizers are expensive, however, because the Haber-Bosch process requires large amounts of fossil fuels to create the conditions of 500°C, 200 atmospheres of pressure, and a catalyst, to produce ammonia nitrogen from nitrogen and hydrogen gases. SA practices, such as the use of slow-release fertilizers, the placement of fertilizer near the crop, and multiple applications of fertilizer, optimize nitrogen use efficiency by crop plants in industrialized systems. Nonetheless, the energy, environmental, and economic cost of nitrogen fertilizer is very high and is sustainable only as long as fossil fuel energy is available to drive the Haber-Bosch process. In contrast, rotation of cereals with nitrogen-fixing legumes, such as beans, peas, or forage crops such as clovers, provides a natural source of organic nitrogen by taking advantage of symbiotic relationships between certain plants and bacteria.

Agrarian farmers have minimal access to nitrogen fertilizer due mainly to cost. Integration of animal manure in their production system and the rotation of nitrogen-fixing crops can sustainably replace the need for nitrogen fertilizer. Farm animals can be used to glean unharvestable grains or plant biomass while spreading their waste in the field. Nitrogen-fixing shrubs such as *Sesbania*, legumes, or *Azolla-Anabaena* (the water fern) may be used as off-season crops to accumulate nitrogen in soils for its eventual use by grain crops. Polyculture offers the potential of interplanting nitrogen-producing crops with those requiring nitrogen. In Luke 19, Jesus told a parable about a man of noble birth who invested resources with his servants. After returning, two servants reported that they invested their minas in a way that earned more minas. God provides people with many resources of different types with the expectation that we are to use these resources wisely. By analogy, water and nitrogen can be viewed as resources that we should invest. If we do so wisely, we not only produce the meaningful outcome of a food crop, but we also improve soil quality by building organic matter such that the water from future rains will be stored in quality soils, enabling the sustained production of ever greater crop yields.

What Kind of Agriculture Should People in Developed Societies Promote?

It is tempting to believe that Western affluence is tied to the efficiency and productivity of the industrial food production model, and then to advocate adoption of the industrial model in developing countries as a solution to both poverty and hunger problems. Before boldly advocating such a change, however, we as foreigners and strangers should remind ourselves of Paul's exhortation to the Philippians, "Do nothing out of selfish ambition or vain conceit, but in humility consider others better than you. Each of you should look not only to your own interests, but also to the interests of others" (Phil. 2:3–4). Those of us from industrialized countries tend to be arrogant because we have been successful by some measures. We often go to poorer countries for a temporary stay to advocate our way of life, having all the power plus a safety net back home to fall back on.

Whereas industrial food production systems use labor efficiently and do produce high yields of a single crop, wholesale adoption of this model could be very harmful to small shareholder, agrarian farmers. First, promoting an industrial production system would be prohibitively expensive. Industrial systems rely on equipment, pesticide, fertilizer, and seed technologies that are expensive, and small shareholder farmers lack large cash reserves. Second, industrialized systems drive labor efficiency. While labor is cost prohibitive in industrialized systems where less than 2% of the population farm, more than 80% of people farm in many agrarian cultures, and consequently labor is valued differently in such places. The main point of this argument is that we should actively promote the adoption of SA principles and facilitate the development of place-appropriate SA practices in support of those principles.

Simply put, many industrial SA practices are irrelevant to the needs of small shareholder farmers in agrarian systems. Sustainable practices such as no-till farming, precision placement of nitrogen fertilizer, and low-pressure irrigation systems are conflated with the industrialized system. To adopt these SA practices requires agrarian farmers to adopt the entire industrialized system, a system that fails to provide the outputs required by the very poor, does not utilize well the resources that the poor do have, and that even in industrialized countries needs considerable reform!

In Cambodia, for example, there is plenty of human labor, with approximately 80% of the population working as rural farmers, each managing a few hectares. Adoption of large modern equipment such as planters and combines would replace the livelihoods of much of the population. Small shareholder farmers need a different sort of efficiency, more quality calories per unit of time, and high-use efficiency of limiting resources such as water, fertilizer, and pesticides. The use efficiencies of water, fertilizer, and pesticides tend to be low in industrialized systems in deference to human labor costs. For example, industrialized food production requires ten kilocalories of fossil fuel energy to produce one kilocalorie of supermarket food, much of which is corn and soybean.[34] Much of the ten kilocalorie energy cost is invested in nitrogen fertilizer which is applied to corn in one application before planting instead of in many small doses throughout the growing season. Nitrogen use efficiency ranges from 15–16%, with most being lost to the atmosphere or ground water. The corn produced is used for animal feed, high fructose corn syrup, or ethanol—hardly quality calories. Alternatively, people in agrarian systems can gain yield advantages even by using practices such as trickle irrigation, fertilizing with lower doses of nutrients more often, or growing crops in polyculture to take advantage of nitrogen-fixing plants while disturbing pest life cycles, thereby reducing the need for pesticides. Recognizing how efficiency is defined and rewarded is extremely important.

Since at least the 1980s, SA practices have been and continue to be adopted by growers who use the industrialized production process. These practices essentially represent incremental improvements to the industrialized process that developed from the 1950s to the 1980s, in an effort to reduce damage caused by the system. To advocate that agrarian farmers change their production practices to an industrialized system would certainly produce for them the same kinds of environmental degradation experienced here.

While agrarian systems are certainly not immune to the potential to degrade environmental resources, it seems more sensible to develop SA practices for existing systems. The opportunities and constraints of small shareholder farmers are unique. A clear understanding of the goals and principles of SA that is fully aware of the current opportunities and challenges of small farmers in poorer countries is required. Micah 6:8 offers us a great reminder that we are to "serve humbly" when making particular recommendations from a position of power. These small farmers who are completely reliant on their land for virtually all of their subsistence may have something to teach us about ecological literacy and long-term sustainability.

Apply the Principles of Sustainable Agriculture to the Very Poor

Food production practices of industrial and agrarian food production systems reflect principles of SA and biblical norms, informing us how we should serve and protect our environment. However, these practices differ from place to place, because they represent place-contextualized approaches of meeting creation care objectives. A reduction or elimination of pesticides and minimal use of fertilizer reduces the pollution load on the land. No-till farming, terraces, or grassy waterways decrease soil erosion, protecting our soil resources. Crop rotation and green manure renew soil. Greater biodiversity improves agroecosystem resilience, provides predators to crop-damaging insects, and increases production potential. While the particular practices of industrial SA may or may not apply to agrarian systems or vice versa, the principles and biblical norms supporting them certainly do.

A comparison of industrialized and agrarian food production systems helps to identify opportunities and threats in both situations. Neither is fully sustainable, yet the practices of one can inform the other in valuable ways. If we are to truly engage the "serve humbly" spirit of Micah 6:8, small- and industrialized-system farmers could empower one another in mutually supportive ways. A vital exchange of ideas, technologies, and practices consistent with the principles and biblical norms of SA has the potential to drive the development of contextually meaningful food production systems that are more economically, socially, and environmentally sustainable. Such an exchange has the potential to create a paradigm shift in both systems, enabling the development of an agroecology that is optimally sustainable and consistent with the dual command of Gen. 2:15 "to serve and protect" God's creation. ✦

Notes

[1]Peter Uvin, "The State of World Hunger," in *The Hunger Report: 1995*, ed. Ellen Messer and Peter Uvin (Amsterdam: Gordon and Breach, 1996), 1–17, Table 1.6.

[2]Global Health Observatory of the World Health Organization. http://www.who.int/gho/mdg/poverty_hunger/situation_trends_underweight/en/index.html.

[3]Richard A. Hoehn, "Introduction," in *Hunger, 1997: What Governments Can Do* (Silver Spring, MD: Bread for the World Institute, 1996); or United Nations Children's Fund (UNICEF), *The State of the World's Children 1993* (Oxford: Oxford University Press and UNICEF, 1993)

[4]Ibid.

[5]See the Millennium Goal #1, End Poverty and Hunger at http://www.un.org/millenniumgoals/.

[6]See Lev. 19:18; Matt. 19:19, 22:39; Mark 12:31, 33; Luke 10:27; Rom. 13:9; Gal. 5:14; James 2:8.

[7]See Steve Corbett and Brian Fikkert, "McDevelopment: 2.5 Billion People NOT Served," chap. 6 in *When Helping Hurts: How to Alleviate Poverty without Hurting the Poor … and Yourself* (Chicago, IL: Moody Publishers, 2009).

[8]The Christian Reformed World Relief Committee describes the rationale for, goals of, and stories about community transformation activities at http://www.crcna.org/pages/crwrc_communitydev.cfm.

[9]Steven Hall, "Toward a Theology of Sustainable Agriculture," *Perspectives on Science and Christian Faith* 54, no. 2 (2002): 103–7.

[10]E. F. Schumacher describes the concept of "appropriate technology" in his classic book, *Small Is Beautiful: Economics as if People Mattered* (New York: Harper Row, 1975).

[11]Michael Pollan, "Farmer and Chief," *New York Times*, October 12, 2008.

[12]Peter H. Raven, "Science, Sustainability, and the Human Prospect," *Science* 297 (2002): 954–8.

[13]Uvin, "The State of World Hunger," 1–17, Table 1.6; Global Health Observatory of the World Health Organization; and Hoehn, "Introduction."

[14]USDA, Agriculture Fact Book 2001–2002, http://www.usda.gov/factbook/chapter3.htm.

[15]USDA, National Institute of Food and Agriculture, http://www.csrees.usda.gov/qlinks/extension.html.

[16]USDA National Agricultural Library, Alternative Farming Systems Information Center. Definitions and Terms. http://www.nal.usda.gov/afsic/pubs/terms/srb9902.shtml#toc2.

[17]Fact sheets and integrated pest management calculators, prime examples of sustainable agriculture tools available

to conventional corn growers in the US Midwest, can be accessed at the following University of Illinois Extension website: http://ipm.illinois.edu/fieldcrops/insects/european_corn_borer/index.html. Integrated pest management (IPM) is a sustainable agriculture technique designed to ensure that pesticides are applied only when economically necessary. To determine if an insecticide should be sprayed on a cornfield to kill European corn borer larvae, the number one insect pest of corn, farmers input an expected yield of a crop, level of infestation, potential for yield preservation, and crop value in a calculator. The output of this financially based model will produce a "spray" or "no-spray" recommendation that optimizes profitability for that particular situation.

[18]Stephen R. Gliessman, "Agroecology and Agroecosystems," in *Sustainable Agriculture*, ed. Jules Pretty (London: Earthscan, 2005), 104–14.

[19]"International Assessment of Agricultural Knowledge, Science and Technology for Development" was published following an Intergovernmental Plenary Session in Johannesburg, South Africa (2008), http://www.agassessment.org/.

[20]World Resources Institute, 2000–2001. "World Resources," chap. 2 in *Taking Stock of Ecosystems*. Pages 43–68 summarize specific factors of agroecosystems.

[21]David Kline, "An Amish Perspective," in *Sustainable Agriculture*, 30–4.

[22]Susan Emmerich's work on farms and ecological health in the Chesapeake Bay watershed.

[23]Hall, "Toward a Theology of Sustainable Agriculture," 1–5.

[24]Gliessman, "Agroecology and Agroecosystems."

[25]Charles C. Mann, "Our Good Earth," *National Geographic* (2008): 84–107.

[26]Robert F. Service, "A Growing Threat Down on the Farm," *Science* 316 (2007): 1114–7.

[27]E. M. Tegtmeier and M. D. Duffy, "The External Costs of Agricultural Production in the United States," in *Sustainable Agriculture*, 64–89.

[28]Stephen Sherwood, Donald Cole, Charles Crissman, and Myriam Paredes, "From Pesticides to People: Improving Ecosystem Health in the Northern Andes" in *Sustainable Agriculture*, 90–103.

[29]Kline, "An Amish Perspective."

[30]See the World Resources Institute (WRI) to access a global map indicating water availability as a function of geographic location. The supporting caption describes the human population dynamics associated with water availability, http://earthtrends.wri.org/text/population-health/map-265.html.

[31]Jeffrey D. Sachs, "Can Extreme Poverty Be Eliminated?" *Scientific American* (September 2005): 56–65.

[32]Paul Polak, "The Big Potential of Small Farms," *Scientific American* (September 2005): 84–91. Polak is the founder of Affordable Small-Scale Irrigation Technologies developed and marketed by International Development Enterprises, Lakewood, CO.

[33]A number of innovative, simple and inexpensive solutions to water supply and purity in Cambodia were developed by the late Mickey Sampson and his staff. Review the website of Resource Development International, http://www.rdic.org/.

[34]Pollan, "Farmer and Chief."