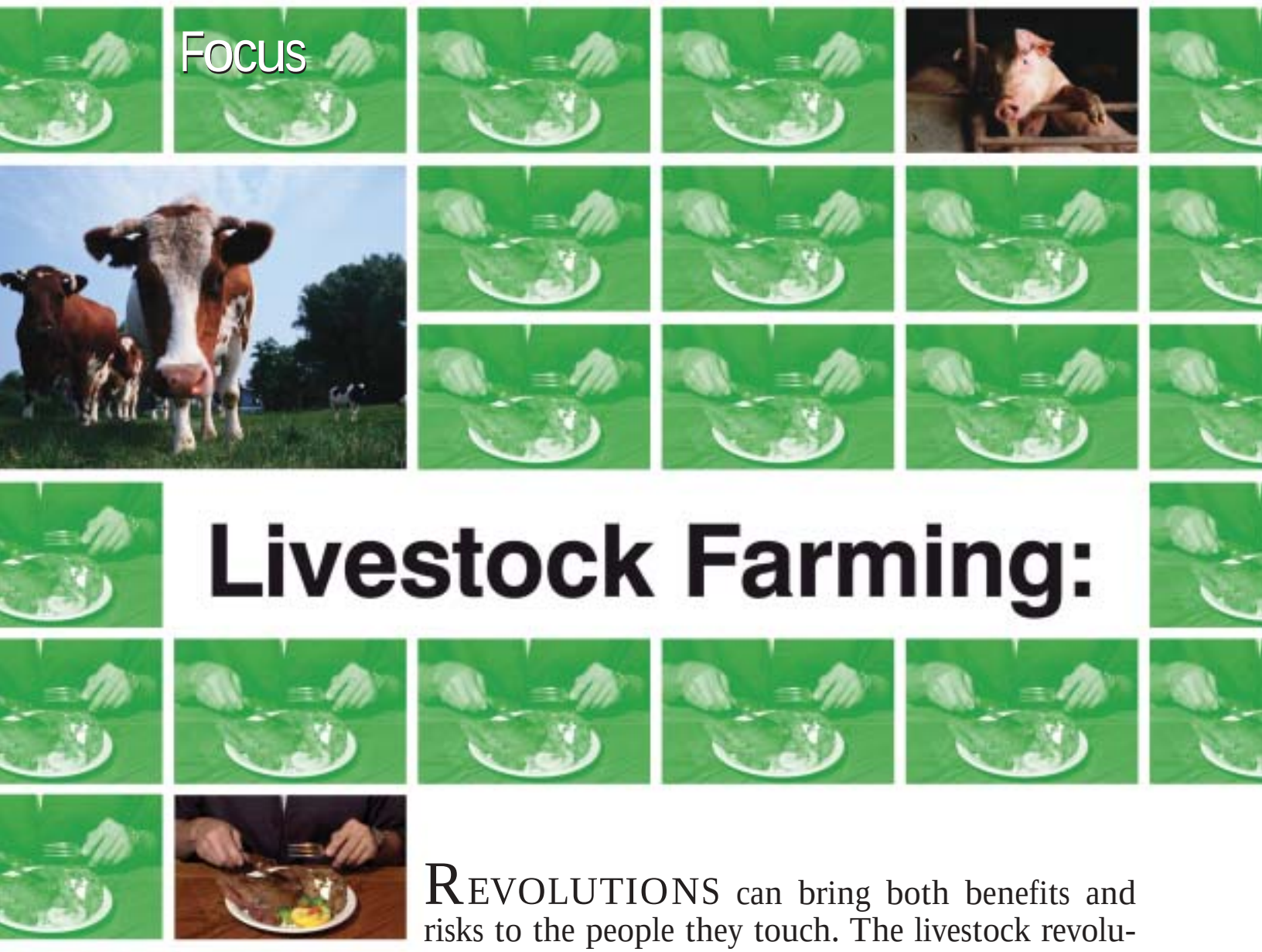

Livestock Farming:

REVOLUTIONS can bring both benefits and risks to the people they touch. The livestock revolution, arising from an increasing worldwide demand for animal products (specifically meat, poultry, and milk), is no different. This growing demand is especially prevalent in developing countries, which historically have consumed far less of animal products on a per capita basis than have developed countries.

According to an analysis presented in *Livestock to 2020: The Next Food Revolution*, a 1999 discussion paper by the Washington, D.C.–based International Food Policy Research Institute, the Food and Agriculture Organization of the United Nations, and the International Livestock Research Institute in Nairobi, Kenya, between 1971 and 1995 consumption rates of meat and milk in developing countries increased by 70 million and 105 million metric tons, respectively. Rates in developed countries during the same time period increased by 26 million metric tons for meat and 50 million metric tons for milk. Increased demand requires increased production. However, the environmental

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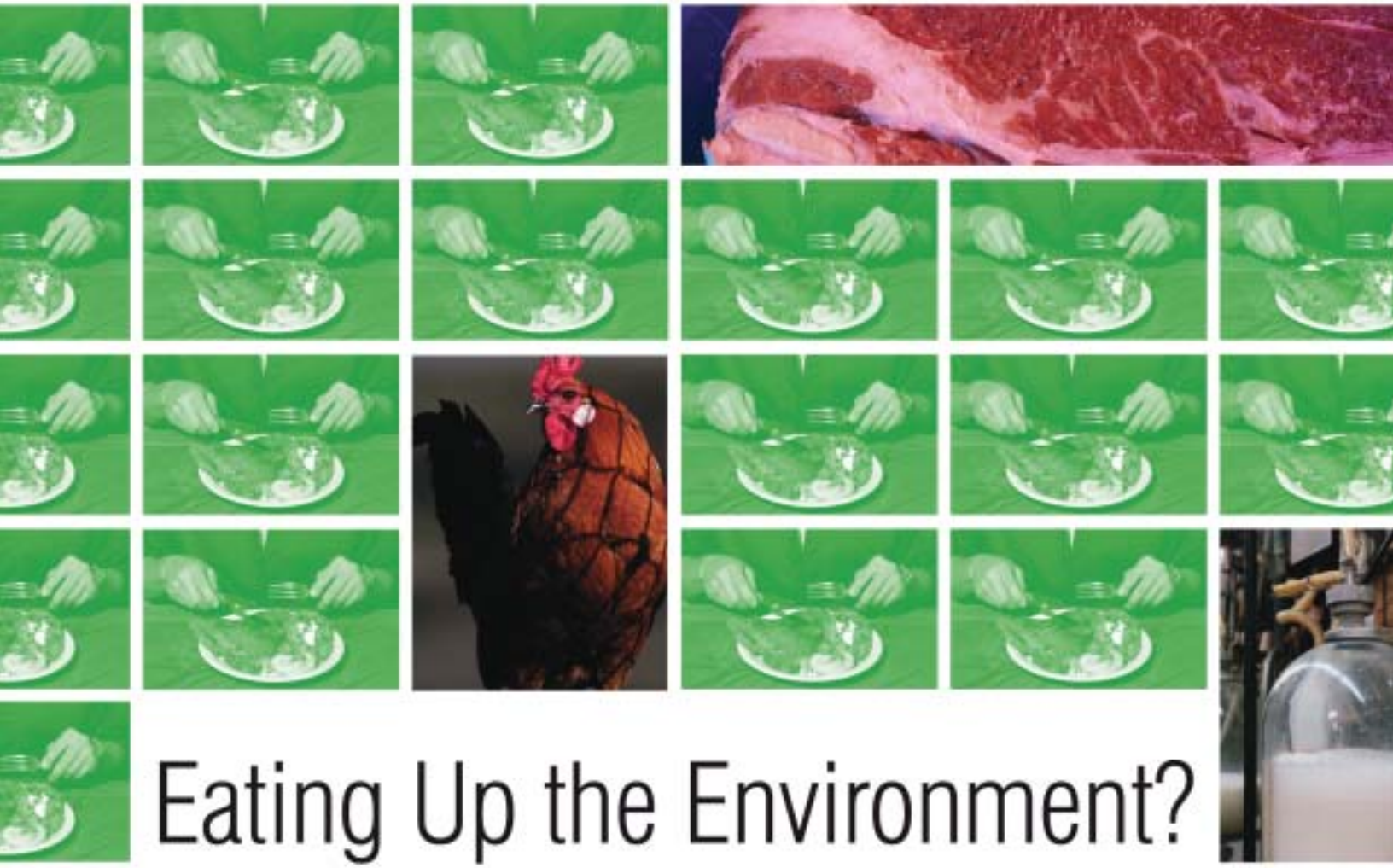

Eating Up the Environment?

consequences associated with livestock are already evident at current production levels where good management is lacking. This raises the concern that increased production might exacerbate existing problems such as deforestation, diminishing biodiversity, soil erosion, greenhouse gas emissions, water pollution, and human disease risk.

A Growing Hunger

Population growth explains some, though not all, of the increased consumption of animal products. Current United Nations projections put the worldwide population at 7.7 billion by 2020, an increase of more than 1.5 billion people over 2000. The majority of the world's new citizens will be born in developing countries. The growth of urban areas is another notable population trend. Urbanization contributes to increased demand for animal products, possibly due to better availability of diverse food options in urban areas. Finally, some developing countries are becoming wealthier. The average gross national product on a per capita basis increased 2.1% annually between 1970 and 1995. And as incomes

increase, people are better able to afford animal products.

Compared to developed countries, per capita consumption of animal products in developing countries is modest. In the last 20 years, per capita consumption has remained stable for meat and milk in the developed world; in developing countries, per capita consumption has risen an average of 11 kg for meat and 8 kg for milk. Such growth is the cornerstone of the livestock revolution.

"The livestock revolution is really the series of forces going on in developing countries, led from East Asia but by no means confined to it, that are leading to a change in the locus of consumption and production of animal products," explains Christopher Delgado, a senior research fellow at the International Food Policy Research Institute and a coauthor of *Livestock to 2020*. "As the world opens up, you get small increments to income, and people quickly diversify [their diets] into fruits, vegetables, and animal products. The effect operates because, although the increments are small, if they're multiplied by [populations] with nine zeroes on them, the aggregate effect is big." As detailed in *Livestock to 2020* and its recent update, East Asia and especially China account for a significant portion of the increased demand for animal products on a regional basis. In only 14 years, between 1983 and 1997, per capita milk and meat consumption more than doubled in China.

Elsewhere in East Asia, per capita meat consumption rose from 22 to 31 kg per year, and milk consumption remained fairly steady. Milk consumption increased significantly in India, from 46 to 62 kg per capita, but meat consumption in this strongly vegetarian country remained unchanged at 4 kg per capita. As in East Asia, both milk and meat consumption rose in Latin America (comprising the Caribbean nations and South and Central America). Between 1983 and 1997, per capita consumption of milk and meat increased by 19 and 14 kg, respectively.

Meat and milk consumption in other regions remained steady or even declined during the 1983–1997 period. In the developed world, which *Livestock to 2020* defines as including North America, Europe, Israel, Japan, New Zealand, Australia, South Africa, and the former Soviet Union, meat and milk consumption remained virtually unchanged, standing at an average of 74 and 195 kg, respectively, in 1983 and at 75 and 194 kg in 1997.

West Asia and North Africa, which are considered one region in the report, and sub-Saharan Africa also exhibited stagnant growth in per capita meat consumption, remaining at only 10–20 kg per year. Per capita milk consumption decreased in both regions, particularly in West Asia and North Africa, by 15 kg. The decrease in sub-Saharan Africa was smaller but more critical; between 1983 and 1987, per capita milk consumption fell to 30 kg, 13 kg below the developing world average of 43 kg.

Africa has the population growth and urbanization that propel demand, but it doesn't have the income growth, says Delgado. The reasons for this are myriad and include persistent drought, unstable government, crippling foreign debt, and the AIDS crisis. Nevertheless, he says, large urban areas in this region represent pockets of increased demand and production that mirror what is occurring in other areas of the world.

Annual per capita consumption of selected livestock food products and percent of total calories consumed from each product, 1973 and 1993

	Developed countries				Developing countries			
	1973		1993		1973		1993	
	(kg)	(%)	(kg)	(%)	(kg)	(%)	(kg)	(%)
Beef	26	3	25	3	4	1	5	1
Mutton/goat	3	1	3	1	1	0	1	0
Pork	26	4	29	5	4	2	9	3
Poultry	11	1	20	2	2	0	5	1
Eggs	13	2	13	2	2	0	5	1
Milk and milk products, excluding butter	188	9	195	9	29	2	40	3
Four meats	67	10	78	11	11	3	21	6
Four meats, eggs, and milk	268	20	285	21	42	6	65	9

Source: Delgado C, Rosegrant M, Steinfeld H, Ehui S, Courbois C. Livestock to 2020: the next food revolution. Washington, DC:International Food Policy Research Institute, 1999.
Notes: *Four meats* includes beef, pork, mutton/goat, and poultry. *Milk* is cow and buffalo milk and milk products in liquid milk equivalents. Values are three-year moving averages centered on the two years shown; percentages are calculated from three-year moving averages. Food is used to distinguish direct food consumption from uses of animal products as feed, fuel, cosmetics, or coverings.

The Need for Meat

Worldwide, approximately 800 million people are undernourished. Micronutrient deficiency is even more pervasive. For example, according to World Health Organization statistics, as many as 2 billion people suffer iron deficiency, which decreases stamina, lowers resistance to infection, and, among children, impairs the ability to grow and learn. In a presentation at the 2001 American Association for the Advancement of Science annual meeting, Charlotte Neumann, a professor of community health sciences and of pediatrics at the University of California at Los Angeles, reminded the audience that some populations have not experienced any dietary changes due to the livestock revolution. Further, she noted, even in developed countries, diets can be deficient in iron, zinc, vitamins, and calcium, particularly among vegetarians. Animal-source foods are excellent sources of these nutrients, she said.

Previous research, notably the Human Nutrition Collaborative Research Support Program (CRSP), a program of the U.S. Agency for International Development's Office of Nutrition in which Neumann was involved, demonstrates that micronutrient malnutrition profoundly affects people, particularly women and children, who do not have access to an adequate quantity and quality of food. Speaking about CRSP data from a cooperative study of the diets of children in Egypt, Kenya, and Mexico, Neumann says, "What we found, particularly in regard to cognitive ability and mental development, was that those children who had even a little bit of animal-source foods in the diet did better on school performance, cognitive testing, and growth, withstood illness better, and were more active."

Neumann is currently a lead investigator in an intervention study that will test CRSP observations. This study, a collaboration between the University of California at Los Angeles, the University of California at Davis, the University of Nairobi, and the Kenyan ministries of health, education, and agriculture, focuses on schoolchildren in Embu, a rural district in Kenya. Through the study, children at school receive a helping of *githeri*, a local vegetable-based stew that is fortified with either meat, a glass of milk, or cooking oil to reach 350 kilocalories per serving. (A control group not receiving *githeri* during the study will be compensated with a goat given to their household at the study's conclusion.) Key data being collected include the children's ability to learn, cognitive function, school performance, activity, growth, micronutrient status, and illness experience.

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A problem with cereal diets, such as those consumed by the Embu schoolchildren, is that although iron, zinc, and other micronutrients may be present in the grains, high concentrations of fiber and phytate (a phosphorus-containing compound commonly found in plant foods) interfere with their absorption in the gut, explains Neumann. Meat, which alone contributes iron, zinc, and vitamin B_{12}, can also enhance the absorption of nutrients from grains. "Even the presence of a little meat in the mix of cereal grains improves the absorption of iron and zinc," says Neumann.

A further benefit of adding milk or meat to the diet is that these foods are nutrient-dense. That factor is particularly important for toddlers and small children, who do not have the gastric capacity to eat enough grain or other plant-based foods to acquire sufficient energy and nutrients.

To meet the nutrient needs of currently malnourished populations as well as those of an expanding global population, livestock production must increase. Animal disease presents perhaps the greatest impediment to livestock production, and given modern globalization, no country or region is immune. "Nobody can sit on the sidelines," says Delgado. "The kind of diseases that you see, such as foot-and-mouth, have been around forever. [But] for at least the last 50 years they've been under control in the developed countries, which have basically been free of them." One way developing countries have been able to control for such diseases has been through fairly tight restrictions on live animal movements, quarantines, prohibition on certain imports, and other measures.

However, in a globalizing world, such control is becoming increasingly difficult to maintain. Clare Narrod, a livestock economist at the U.S. Department of Agriculture currently working for the Food and Agriculture Organization, speculates that it will be interesting to see whether border control policies might be altered in the wake of the March 2001 European foot-and-mouth disease outbreak. Says Narrod, "Part of what the European Union has done has decreased those border controls as they have moved toward trading amongst each other. When you had borders, you were able to control disease much more easily."

In addition to vaccination and surveillance programs, biotechnology may yield novel ways to diagnose and treat diseases. For example, gene mapping could provide the basis for new generations of vaccines. Another problem is that certain areas, particularly in Africa, offer both arable land and the perfect habitat for insects that carry human disease. The use of insecticides as well as both preventive and treatment drug therapies for humans and animals can make agriculture possible in areas prone to endemic diseases such as river blindness and sleeping sickness.

Not all techniques for boosting production require sophisticated technology, says Bradford. "One of the reasons for low productivity in some countries is that the animals are kept primarily for insurance or as property; that is, for reasons other than production," he says. "If the goal is to produce because there's now a market for the product, modifications of management to reflect this different goal can have a big effect."

Projected trends in meat and milk consumption, 1993–2020

	Projected annual growth of total consumption, 1993–2020 (%)		Total consumption in 2020 (million metric tons)		Per capita consumption in 2020 (kg)	
	Meat	Milk	Meat	Milk	Meat	Milk
China	3.0	2.8	85	17	60	12
Other East Asia	2.4	1.7	8	2	67	20
India	2.9	4.3	8	160	6	125
Other South Asia	3.2	3.4	5	41	10	82
Southeast Asia	3.0	2.7	16	11	24	16
Latin America	2.3	1.9	39	77	59	117
West Asia and North Africa	2.8	3.0	15	51	24	80
Sub-Saharan Africa	3.5	3.8	12	31	11	30
Developing world	2.8	3.3	188	391	30	62
Developed world	0.6	0.2	115	263	83	189
World	1.8	1.7	303	654	39	85

Source: Delgado C, Rosegrant M, Steinfeld H, Ehui S, Courbois C. Livestock to 2020: the next food revolution. Washington, DC:International Food Policy Research Institute, 1999.
Notes: *Consumption* refers to direct use as food, measured as uncooked weight, bone in. *Meat* includes beef, pork, mutton, goat, and poultry. *Milk* is cow and buffalo milk and milk products in liquid milk equivalents. Metric tons and kilograms are three-year moving averages centered on the two years shown.

Reuther/EHP; Tart/EHP; Dooley/EHP; FAO

Livestock production also benefits by improving animal nutrition. As an example, G. Eric Bradford, emeritus professor of animal science at the University of California at Davis, notes that when the forage is deficient, the productivity of grazing animals increases if their diets are supplemented with grain, food processing by-products, or protein. The challenge of improving animal nutrition is also being met by improving feed conversion, or the amount of nutrition an animal can extract from its food. Pretreating crop residues or using feed additives are two ways of accomplishing this goal, but other methods focus on breeding plants that are more digestible. Since the 1980s, there has been a significant increase in animal production owing to better nutrition, increased feed conversion, and improved health. According to Bradford, in both developed and developing countries, the ratio of human food—meat, milk, and eggs—per unit of grain fed to livestock increased by 15%.

A third means of boosting production rests with improved reproductive and genetic technologies. Artificial insemination of livestock has a more than 50-year history in developed countries, and is increasing in developing countries, especially India. Some success has also been seen with crossbreeding hardy animals with high-producing breeds. New genetics research may also allow identification of markers for disease resistance and good performance.

A Costly Meal?

Although the livestock revolution may deliver better nutrition to millions of people, there are risks to both human health and the environment associated it. Meat and dairy products share a burden of blame for the high incidence of cardiovascular disease, obesity, and other so-called diseases of affluence commonly found in developed countries. However, these problems are caused primarily by overconsumption of meat and dairy products and lack of physical activity rather than the foods themselves. Although some research points to a growing incidence of diseases of affluence in the developing world, cases are generally confined to urban areas and affect a very small portion of the population.

Barring diseases of affluence, zoonotic and foodborne diseases pose a potentially serious public health threat. Zoonotic diseases, or illnesses that can be transmitted from animals to people, range from the well-known such as leptospirosis and cryptosporidiosis to the newly emerging such as bovine spongiform encephalopathy (mad

cow disease). According to the U.S. Department of Agriculture's Agricultural Research Service, there are nearly 200 diseases that can be transmitted from animals to people, although of course not all of them are necessarily a threat to public health.

It's not possible to nail down specific numbers on people affected because it depends on the specific situation. An outbreak situation could be minor (for example, a few cases of diarrheal illness) or severe (for example, hundreds of thousands of cases and numerous deaths). The size of the outbreak does not necessarily correlate with the type of threat, which depends on the associated pathogen.

In April 1993 in Milwaukee, Wisconsin, the water supply became contaminated with *Cryptosporidium parvum*, a parasite that causes severe diarrhea. The outbreak was linked to the public water supply, which may have been contaminated by runoff from upstream farms (however, this was not established absolutely). Most victims of *C. parvum* infection recover within a week or two, but young children, the elderly, and immunocompromised individuals are vulnerable to serious complications and death. In the Milwaukee outbreak, more than 400,000 people became ill, 4,400 were hospitalized, and several AIDS patients died.

Some researchers speculate that high animal densities may provide the grounds for breeding novel strains of certain diseases, particularly influenza. An epidemic or even pandemic situation is conceivable, should novel influenza strains materialize. Disease risks are of special concern in urban locations that have substantial livestock populations and inadequate regulation.

Foodborne diseases arise from contaminants including bacteria, viruses, parasites, and chemicals that are ingested along with food. According to estimates from the Centers for Disease Control and Prevention Division of Bacterial and Mycotic Diseases, each year food poisoning causes 76 million illnesses and 5,200 deaths in the United States alone. Not all cases arise from animal product consumption, but such foods do carry a certain measure of risk, particularly if they are prepared improperly. Pinning down the point of contamination is the first step in solving the problem, says Narrod. "This is part of the reason we do farm-to-table risk assessments: we're trying to see where the problem occurs the most," she says.

In addition to health effects associated with livestock consumption, it's not possible to grow or raise enough food for more than 6 billion people without environmental impacts as well. Increasing demand translates to more intense production, hence more pressure on agricultural systems and ultimately on the environment. "I think there are some real concerns, particularly if intensive livestock production increases markedly as it is doing in places like China," says Bradford. "If that occurs without proper environmental regulations, there could be problems."

Livestock agriculture can be generally divided into three types of production systems: grazing, mixed farming, and industrial. In grazing systems, livestock derive most, if not all, of their nutrition from grassland vegetation. According to *Livestock & the Environment: Finding a Balance*, the results of a study coordinated by the Food and Agriculture Organization, the U.S. Agency for International Development, and the World Bank published in 1997, these systems account for approximately 10% of the world's meat production. Mixed farming systems, which combine crop and livestock production, provide the largest share of animal products: 50% of the world's meat and 90% of its milk. However, industrial systems are experiencing significant growth, particularly with regard to pork and poultry production, and currently supply slightly less than 40% of the world's meat.

Grazing and mixed farming systems are considered relatively closed systems—that is, the inputs and outputs are relatively contained—whereas industrial systems rely on external contacts. Unlike grazing and some mixed farming systems, industrial systems cannot operate as self-contained units. Not only are animals often born, raised, bred, and slaughtered at different locations, but feed has to be brought in and waste hauled out at each location. Each system has its benefits and drawbacks. However, according to Cornelis de Haan, a livestock expert at the World Bank and coauthor of *Livestock & the Environment*, it's not so much agriculture that poses environmental problems as its management.

Given that there's a finite amount of available land, producers may use land too intensely—for example, by overgrazing—past what is sustainable. Land unsuitable for crop production can be used for grazing, but if the pressure is great enough it may be brought into crop production. Likewise, grazing may be pushed onto land marginal for the purpose. Symptoms of land degradation include losses of productivity and biodiversity.

There are few places that illustrate the effects of poor land management better than the Amazon River basin. Attention was focused on this area in the late 1980s with heavy criticism of the "hamburger connection." Supposedly, ranchers were destroying large tracts of the Amazon to raise cattle that would eventually be served up as hamburgers in American fast-food restaurants. However, ranchers were at the tail end of policies in place during the 1960s and 1970s that encouraged road building, logging, and colonization in the Amazon. Once the land was cleared, it rapidly lost fertility. Consequently, colonists could sustain agricultural crops for only a short time before resorting to ranching. Ranching, which doesn't require nutrient-rich soil, took the place vacated by other activities, along with the blame for soil erosion and loss of biodiversity.

As with land, water is also a finite resource and can be a limiting factor to increasing production. Livestock require large amounts of water. In arid regions, this

Projected production of various livestock products, 1993–2020

	Projected annual growth of total production (%)	Total production (million metric tons)		Per capita production (kg)	
	1993–2020	1993	2020	1993	2020
Developed world					
Beef	0.6	35	38	26	28
Pork	0.4	37	41	29	29
Poultry	1.2	27	36	21	26
Meat	0.7	100	121	78	87
Milk	0.4	348	371	272	267
Developing world					
Beef	2.6	22	44	5	7
Pork	2.7	39	81	9	13
Poultry	3.0	21	47	5	7
Meat	2.7	88	183	21	29
Milk	3.2	164	401	39	63

Source: Delgado C, Rosegrant M, Steinfeld H, Ehui S, Courbois C. Livestock to 2020: the next food revolution. Washington, DC:International Food Policy Research Institute, 1999.
Notes: *Meat* includes beef, pork, mutton, goat, and poultry. *Milk* is cow and buffalo milk and milk products in liquid milk equivalents. Metric tons and kilograms are three-year moving averages centered on the two years shown.

Reuther/EHP; Tart/EHP; Dooley/EHP; USDA

need can place them in direct competition with other users, including humans and wildlife. Further, the practice of enhancing a region's water resources through sinking wells, irrigating, and otherwise developing supplies may artificially inflate the local carrying capacity. In addition to overwhelming the local ecosystem, should the developed supply fail, the livestock will not survive without emergency assistance.

In other regions, irrigation is necessary to grow crops intended as livestock feed. Depending on how quickly the water is replaced, it may not be sustainable, especially under drought conditions. Irrigation also has the potential to rob other areas of needed water, which can affect downstream communities and ecosystems.

Improperly managed, crop and livestock production can pollute water resources. Water pollution can also occur if processors do not manage slaughter waste properly. Animal waste and fertilizer runoff overload surface waters with nutrients, and pesticides and other chemicals can leach into ground waters. Animal waste problems are especially prominent in regions where industrial systems are concentrated. Such regions include northwestern Europe, the northeastern United States, and densely populated areas in Asia. Unlike grazing and mixed farming systems, which use animal waste to replenish soil nutrients, industrial systems produce far more waste than the surrounding land can absorb.

Consequently, excess nitrogen and phosphorus leach into ground waters or run off into surface waters. Groundwater nitrate contamination can render the water unsafe to drink, and runoff is directly linked to nutrient overload in surface waters. These excess nutrients promote overgrowth of water vegetation. As the vegetation decays, aquatic wildlife are deprived of oxygen, and large-scale die-offs occur. Eventually, the buildup of organic matter in the water can change an entire ecosystem. Animal waste runoff may also pose a risk to human health.

Finally, by both direct and indirect means, livestock emit enough carbon dioxide, methane, and nitrous oxide to have a role in global warming. Livestock emit carbon dioxide as part of normal respiration—collectively, an estimated 2.8 billion metric tons annually. Indirectly, carbon dioxide is emitted in conjunction with biomass burning (burning related to land clearing) and fossil fuel consumption connected to transport and manufacturing.

Livestock are also responsible for approximately 88 million tons of methane per year, which accounts for 16% of annual global production. Approximately 80% of the methane is emitted as a by-product of ruminant digestion. The remaining 20% is produced through storing manure, for example in holding ponds. Manure also produces nitrous oxide, which is the most damaging of the greenhouse gases—it is 320 times more effective than carbon dioxide at holding heat in the atmosphere.

"Intensive livestock production doesn't have to be environmentally undesirable," Bradford says, "but it is likely to be so unless the necessary steps are taken." Martha Noble, senior policy analyst at the Sustainable Agriculture Coalition in Washington, D.C., notes that such steps may be found in good management practices. "There are certainly good or better management practices for just about any environmental problem that agriculture can impose," she says.

In *Livestock & the Environment*, de Haan and his coauthors detailed key considerations in determining environmental policies. The normal status of a particular area should be recognized, including the soil type, climate, and factors related to aridity. Current conditions need to be properly assessed prior to implementing policies to correct them. Laws are needed in a wide variety of areas, including waste regulation, zoning, and land use, and they need to be enforced. Other policies could address the establishment of protected areas and the use of price controls and incentives to internalize environmental costs.

"I feel strongly that we have the technologies basically to mitigate those negative effects," says de Haan, "but it's very much a question of getting the policy environment right. There needs to be a political will to do so."

Just Desserts?

The environmental impacts of livestock farming are not universally negative. In addition to grazing animals on land that is not suitable for cropping, ruminants consume crop residues, food processing residues, and other waste that is inedible by people. Grazing systems have the potential to increase biodiversity and can improve soil cover and vegetation. In some regions, livestock are used for draft power, which decreases farmers' reliance on fossil fuels and mechanization. In both grazing and mixed farming systems, animal manure benefits the soil.

The environmental benefits of industrial systems may seem elusive, but they do exist. For example, concentrating animal production in one area uses less land, though by divorcing livestock production from crop production, other problems may be created. "One of the big problems that we're seeing now in the United States and in other parts of the world with the confined animal systems is that we get this double whammy," says Noble. As animals are removed from the land, it eliminates the possibility of grazing so that some kind of row crop must be grown for feed grain. In addition, it creates a vast amount of animal waste. "The further you separate [animal and crop production] geographically, the bigger potentials you get for problems, expense, and external cost to communities," she says.

Though the livestock revolution is demand-driven, meeting the demand has implications beyond relieving hunger and ensuring environmental sustainability. As noted in *Livestock & the Environment*, raising livestock provides the sole livelihood for 20 million families and is an important income source for an additional 200 million families. Basic issues such as food security outweigh environmental issues in many areas of the world. "A lot of countries look at . . . increased livestock production and all the negative externalities such as environmental impacts. Then they say, 'Why should we be concerned? We're trying to increase access to protein for our people,'" observes Narrod.

Delgado suggests that the solutions for balancing the demand for livestock and its associated economic issues with environmental health issues must involve the people most affected by these issues. Consider Africa and China, he suggests. In those regions, approximately 75% of the population is rural. "If you take livestock away from people, you have a poverty problem," he says. "[But] if the part of the market that is growing is primarily urban and is getting supplied from industrial sources, then there really is a major social issue there [for the environment]," he says. "I don't think that there is any solution that doesn't involve investing in improved institutions in rural areas."

Finding a balance between meeting the world's nutrient requirements and protecting its resources is an enormous challenge. Meeting this challenge calls for understanding myriad interrelated factors, including economics, poverty alleviation, population growth and urbanization, and agroecosystem dynamics. In short, the term *revolution* is not used lightly.

"The livestock revolution is going to happen," Delgado assured attendees at the 2001 American Association for the Advancement of Science meeting. "It's really not a matter being decided in Washington or somewhere else; this is something that four billion people are deciding on their own. Whether it's a curse or a blessing depends a lot upon proactive policies."

Julia R. Barrett