An HSUS Report: The Impact of Animal Agriculture on Global Warming and Climate Change

Abstract

The farm animal production sector is the single largest anthropogenic user of land, contributing to soil degradation, dwindling water supplies, and air pollution, in addition to detrimentally impacting rural and urban communities, public health, and animal welfare. The breadth of this sector's global impacts has been largely underestimated and underappreciated. Indeed, meat, egg, and milk production are not narrowly focused on the direct rearing and slaughtering of farm animals. Rather, the animal agriculture sector encompasses grain and fertilizer production, substantial water use, and significant energy expenditures to transport feed, farm animals, and finished meat, egg, and dairy products.

Animal agriculture's greatest environmental influence may be its contributions to global warming and climate change. According to the Food and Agriculture Organization (FAO) of the United Nations (UN), the animal agriculture sector is responsible for 18%, or nearly one-fifth, of human-induced greenhouse gas (GHG) emissions, greater than the share contributed by the transportation sector. In nearly every step of meat, egg, and dairy production, climate-changing gases are released into the atmosphere, disrupting weather, temperature, and ecosystem health. Mitigating and preventing these serious problems requires immediate and far-reaching changes in current animal agriculture practices and consumption patterns.

Global Warming and Climate Change

Global warming refers to an increase in average global temperatures, which in turn causes climate change, such as changes in seasonal temperatures and wind velocity, and the amount of precipitation and humidity for a given area or region.[1] Climate change can involve either cooling or warming.

Evidence suggests that the planet is presently experiencing a warming trend. Temperature readings taken around the world in recent decades, as well as scientific studies of tree rings, coral reefs, and ice cores, show that average global temperatures have risen substantially since the Industrial Revolution began in the mid-1700s.[2] Of particular concern is the fact that these increases have been accelerating more rapidly over the past few decades. The UN's World Meteorological Organization has concluded that, for January and April 2007, "it is likely that global land surface temperatures ranked warmest since records began in 1880, 1.89°C [3.40°F] warmer than average for January and 1.37°C [2.47°F] warmer than average for April."[3] The five warmest years ever recorded have all occurred since 1998, and there has been a mean surface temperature increase of about 0.6°C (1.08°F) in just the last 30 years.[4]

Worldwide, glaciers are in retreat, the tundra is thawing, sea ice is melting, the sea level is rising, and some species are rapidly disappearing.[5] In 2007, the U.S. Geological Survey (USGS) announced its prediction that changes in sea ice conditions could result in a loss of two-thirds of the world's polar bear population by 2050.[6] USGS reportedly identified "a definite link between changes in the sea ice and the welfare of polar bears…As the sea ice goes, so goes the polar bear."[7]

Weather pattern shifts and extreme weather events, such as hurricanes, are also appearing to occur more frequently.[8] Both the prevalence and intensity of these changes are expected to increase as GHG emissions rise during the 21st century. The Intergovernmental Panel on Climate Change (IPCC) predicts temperature rises of 1.8-4.0°C (3.2-7.2°F) by 2100.[9]

Some natural occurrences, such as volcanic eruptions, lightning, and natural fires, contribute to GHG emissions;[10,11] however, the overwhelming consensus among the world's most reputable climate scientists is that a majority of the increase in temperature is due to human activities.[12] In fact, the IPCC has found with "high confidence" that human endeavors are partly responsible for a variety of climatic changes happening already.[13] The panel concluded, for example, that "[h]uman influences have very likely contributed to sea level rise during the latter half of the 20th Century" and that changing wind patterns and increased temperature extremes have "likely" been a result of human activities.[14] The IPCC's report released in November 2007, widely considered one of the most important documents ever released on the issue of climate change and global warming, warns that climate change could have "abrupt or irreversible" effects.[15]

The IPCC and Al Gore, Jr., former Vice President of the United States, were jointly awarded the Nobel Peace Prize for 2007 "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change."[16]

Causes of Global Warming and Climate Change

Three major gases facilitate climate change: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).[17] In naturally occurring quantities, these gases are not harmful; their presence in the atmosphere helps to sustain life on the planet by trapping some heat near the Earth's surface. Over the past century, however, human activities have added additional GHGs to the atmosphere, contributing to global warming and climate change.[18]

While most of the concern about GHGs tends to focus on carbon dioxide, methane and nitrous oxide are also extremely potent gases. The global warming potential (GWP), or power, of each of these gases differs. CO_2 has been assigned a value of one GWP, and the warming potentials of other gases are expressed relative to its power on a CO_2-equivalent basis.[19] For example, 1 tonne* of methane has the warming effect of around 23 tonnes of CO_2, while 1 tonne of nitrous oxide has the warming effect of around 296 tonnes of CO_2.[17]

Gas	Global Warming Potential
Carbon dioxide (CO_2)	1
Methane (CH_4)	23
Nitrous oxide (N_2O)	296

Transportation and the burning of fossil fuels have traditionally been viewed as the largest contributors to climate change. Passenger and commercial vehicles, including cars, trucks, and sport utility vehicles (SUVs), contaminate the air by emitting CO_2 into the atmosphere. In the United States alone, personal vehicles emit more than 300 million tonnes of CO_2 each year.[20] Additionally, coal-fired power plants expel nitrous oxide and carbon dioxide into the air, contributing to acid rain and pollution.

A 2006 investigation by the FAO highlighted the environmental impacts of farm animal production. In both industrialized and developing regions, the animal agriculture sector plays a substantial role in climate change. Indeed, according to the FAO, the sector is "a major player"[21] in climate change and "a major threat to [the] environment,"[22] with nearly every step in the production chain contributing to air pollution or climate change. The agency's November 2006 report, "Livestock's Long Shadow: Environmental Issues and Options," found that meat, egg, and milk production are responsible for 18%, or nearly one-fifth, of human-induced GHGs, more than cars, SUVs, and other vehicles.[23]

* One tonne is one metric ton, or 1,000 kg (approximately 2,205 lb).

Global Farm Animal Populations and Production Practices

Farm animals are significant contributors to the production of all three major GHGs[17] and, as their numbers grow, so do their emissions. As the U.S. Department of Agriculture (USDA) notes, "GHG emissions from livestock are inherently tied to livestock population sizes because the livestock are either directly or indirectly the source for the emissions."[24]

According to the FAO, globally, approximately 63 billion land animals[25] were raised for human consumption in 2007, joined by an untold number of aquatic animals. Presently, traditional (extensive, or pasture-based) farming methods still remain widespread in Africa and parts of Asia, but the reach of industrialized animal agribusiness practices customary in the United States and Europe has extended into less-developed countries. Globally, industrial systems account for an estimated 67% of poultry meat production, 50% of egg production, and 42% of pork production.[26] In China, India, and Brazil, for example, producers are increasingly favoring intensive, industrial production systems[26] over more welfare-friendly practices. "In recent years, industrial livestock production has grown at twice the rate of more traditional mixed farming systems and at more than six times the rate of production based on grazing," according to a 2007 report about GHG emissions from agriculture.[27]

This inhumane and environmentally unsustainable trend toward industrial practices views farm animals as "production units" and focuses nearly exclusively on productivity as the sole output of these industries. Emphasizing productivity can often be at odds with animal welfare and, as a result, has severely reduced the health and well-being of farm animals. Additionally, rearing greater numbers of animals has intensified agricultural production practices that today typically confine animals in cages, crates, pens, stalls, and warehouse-like "grow-out" facilities without environmental stimulation or adequate space for animals to experience most natural behavior. In addition to these impacts on animal welfare, "If animals are considered as 'food production machines'," a team of Swiss and Italian scientists concluded, "these machines turn out to be extremely polluting…and to be very inefficient."[28]

Greater Numbers of Farm Animals and Greater Environmental Impacts

By 2050, global farm animal production is expected to double from present levels, with most of those increases in the developing world.[29] As animal agriculture operations become further separated from agricultural land, increasingly moving greater numbers of animals indoors without provision for any outdoor access, the environmental problems they create are becoming more harmful. Massive production facilities are typically located too far from cropland to efficiently use manure for fertilizer, making them "landless" as opposed to land-based traditional farms.[30,31] Instead, "manure is distributed to a small, local landmass resulting in soil accumulation and runoff of phosphorus, nitrogen, and other pollutants."[31]

According to the Pew Center on Global Climate Change, growth in farm animal populations, particularly in large, confined operations, has greatly increased emissions of methane from both animals and their manure since the 1940s. The Pew Center also notes that the growing use of industrial fertilizers over the last 50 years—with a significant percentage going toward farm animal feed production—has considerably elevated artificial nitrogen inputs to the soil. This in turn has led to increases in nitrous oxide emissions.[32] CO_2 emissions are also rising as a result of animal agriculture. The burning of fossil fuels is necessary in the production of feed and fertilizers, while tropical forests and other carbon sinks (places that sequester or hold carbon and prevent its emission into the atmosphere) are destroyed to create grazing land or fields to grow feed.[33]

As the environmental consequences of animal agriculture become more clear, governments, development organizations, non-governmental organizations (NGOs), and the media are joining animal welfare NGOs in focusing more attention on meat, egg, and dairy production.

The world's leading authorities on agricultural development, in particular, have recognized the destructive potential of today's farm animal production practices. According to Henning Steinfeld, head of the FAO's

Livestock Information and Policy Branch and senior author of "Livestock's Long Shadow," "Livestock are one of the most significant contributors to today's most serious environmental problems. Urgent action is required to remedy the situation."[22]

Fueling Climate Change: Carbon Dioxide

Carbon dioxide is widely considered the most important GHG. The increase in atmospheric CO_2 concentration from deforestation and the burning of fossil fuels is the largest of all the human and natural influences on climate over the last 250 years.[34] The IPCC reports that the global atmospheric concentration of carbon dioxide has increased from approximately 280 parts per million (ppm) in 1750 to 379 ppm in 2005—an increase of more than 30%.[2]

CO_2 has the most significant direct warming impact in the atmosphere for two reasons: 1) the sheer volume of its emissions and 2) its persistence in the atmosphere. While some GHGs have a half-life of decades, the half-life of carbon dioxide is at least 100 years.[17,35] Most of the CO_2 that is released today, including emissions produced by the animal agriculture sector, may continue to linger in the atmosphere in 2100.[35] The farm animal sector contributes approximately 9% of annual anthropogenic CO_2 output. The largest sources of CO_2 from animal agriculture come not from the animals themselves, but from the inputs and land-use changes necessary to maintain and feed them.[36]

Fertilizer and Feed Production

Burning fossil fuel to produce fertilizers used in feed production may emit 41 million tonnes of CO_2 per year.[37] Indeed, a main input in modern meat, egg, and dairy production is artificial nitrogenous fertilizer, vast amounts of which are used in the cultivation of farm animal feed, primarily a combination of corn and soybeans. Most of that fertilizer is produced in factories dependent on fossil-fuel energy. Every year, 100 million tonnes of artificial fertilizer are manufactured using the Haber-Bosch process, a method that produces ammonia, which is then used to make nitrogen-based artificial fertilizer. Manufacturing fertilizer uses roughly 1% of the world's total energy, and an estimated 41 million tonnes of CO_2 is emitted from fertilizer production exclusively for feed crops.[38]

China, the world's largest producer of grain,[25] emits the greatest amount of CO_2 from this process, releasing nearly 14.3 million tonnes annually. The United States, the world's second-largest grain producer,[25] emits just under 12 million tonnes, while Canada, France, Germany, and the United Kingdom each emits 2.2-3.3 million tonnes of CO_2 per year as a result of fertilizer production.[39]

The ammonia industry accounted for approximately 5% of natural gas consumption in the mid-1990s. While cleaner burning natural gas is typically used to produce ammonia, a wide range of energy sources can be used, including coal. In China, for example, 60% of its nitrogen fertilizer is made using coal in small plants that are relatively energy-inefficient compared to those using natural gas.[37] In turn, these plants contribute to emissions of nitrous oxide and other pollutants into the atmosphere.

Energy Use

Maintaining large-scale, industrial animal production facilities, commonly referred to as factory farms, may emit 90 million tonnes of CO_2 per year[39] as they can require substantial energy inputs. The fossil-fuel use in these intensive confinement operations differs significantly from that of much smaller-scale, extensive farms where animals are often raised outdoors. The FAO estimates that operating factory farming systems likely produces more CO_2 emissions than does the manufacturing of chemical fertilizer for feed production. The fossil fuel needed varies by animal: A typical U.S. factory farm in the 1980s used approximately 35 megajoules (MJ) of energy per kg of a chicken, 46 MJ per kg of a pig, and 51 MJ per kg of cattle.[39]

Electricity for heating, cooling, and ventilating large-scale factory farms makes up a large part of this energy expenditure, but, according to the FAO, more than half of the energy used for intensive animal agriculture systems is used for feed production. This does not include the energy used to make fertilizer (discussed above), but the energy used to produce seed, herbicides, and pesticides, as well as the fossil fuel needed for farm machinery used to produce feed.[40] Furthermore, converting plant matter into animal protein by feeding it to farm animals wastes a great deal of protein and energy as "vegetables consumed as feed are used by the animals for their metabolic processes, as well as to build non-edible tissue like bones, cartilage, offal and faeces."[41]

In contrast, extensive animal production farms typically have very low energy expenditures. In addition to being much smaller than intensive confinement operations, these farms, particularly in the developing world, tend to use animals to provide most of the energy needed to cultivate fields or transport products to markets.[15] Even in the United States, Amish farms[42,43] and, increasingly, organic producers use animals for draught power to reduce energy costs on the farm.[44]

Transportation and Processing

Transporting feed, and processing and transporting animal products emit several million tonnes of CO_2 per year.[45] Fewer than 50 years ago in the United States, most foods, including meat, eggs, and dairy, were consumed relatively close to where they were produced. Today, food typically travels 2,500-4,000 km (1,553.4-2,485.5 mi) from farm to table, as much as 25% farther than in 1980.[46]

As agriculture becomes increasingly globalized, meat, eggs, milk, and live animals are transported farther than ever before. Approximately 45 million cattle, pigs, and sheep are traded around the world each year,[25] and millions more are transported over long distances within a country's own borders.[47] In addition to the human health and animal welfare implications of transporting live animals short and long distances alike and the potential for spreading animal disease,[48] there are significant fossil fuel and climate costs.

While the FAO did not include consideration of live animal transport in its calculations, its report did find that transporting feed and animal products to the destinations where they will be consumed emits approximately 0.8 million tonnes of CO_2 per year. These transport costs come in two stages—first, when processed feed is delivered to animal production facilities and second, when animal products are delivered to consumer markets.[49]

Soybeans and soybean cakes used for feed are shipped from Brazil to Europe, and estimated annual emissions of CO_2 from just this single trade route are some 32,000 tonnes. The annual trade of meat between countries results in 500,000-850,000 tonnes of CO_2.[50]

In July 2007, a team of Japanese researchers found that producing 1 kg (2.2 lb) of beef results in GHG emissions equivalent to 36.4 kg (80.25 lb) of CO_2, with almost all energy consumption attributed to production and transport of feed.[51,52] A *New Scientist* article summarizing the study's findings put this figure into perspective by concluding that "a kilogram [2.2 lb] of beef is responsible for the equivalent of the amount of CO_2 emitted by the average European car every 250 kilometres [155 mi], and burns enough energy to light a 100-watt bulb for nearly 20 days." The article also noted that the study's findings would have exceeded this figure if the researchers had included the impacts of managing farm infrastructure and transporting final products to market.[52]

The amount of fossil fuels burned for processing animals varies significantly. The FAO estimates that CO_2 emissions from animal processing total several tens of millions of tonnes per year.[53] There are, however, significant data gaps regarding meat, dairy, and egg processing, making it impossible to know the true carbon costs of all farm animal products. Processed animal products typically come from factory farms and tend to be highly energy intensive. Meat produced from sheep, for example, is very energy costly, with 10.4 MJ used per kg of meat compared to the energy required for processing beef, which uses 4.37 MJ per kg. Processing eggs, too, is energy intensive, with more than 6 MJ used per dozen eggs, and processing newly slaughtered pigs takes about half as much energy as turning pig carcasses into processed pork products.[45]

Disturbing the Nitrogen Cycle: Fertilizer and Feed Production

According to University of Manitoba Distinguished Professor Vaclav Smil, most of the world's grain production does not feed people directly, but is instead fed to farm animals. Some 50% of the global corn crop and up to 80% of the global soybean crop are fed to cattle, pigs, and chickens.[54] Modern corn varieties are especially dependent on nitrogen-based artificial fertilizers to grow.

Natural sources of fixed nitrogen—the form of nitrogen that is easily available as fertilizer for plants—are in short supply. As a result, fertilizers are made artificially. Low-cost techniques for synthesizing ammonia emerged shortly after World War II, and cheap ammonia then led to the mass production of artificial fertilizers. Before the Haber-Bosch process was developed, the amount of life the planet could support was limited by the amount of nitrogen made available to plants by bacteria and lightning. These bacteria have enzymes that are capable of breaking the bonds of N_2, the most stable form of nitrogen, while the energy force of lightning is strong enough to break the bonds of N_2 and make it available for plants and animals. For crop farmers in the industrialized world and, increasingly, the developing world, this once-limited nutrient is now available in virtually limitless quantities.[55]

These innovations have come at a cost. Smil, who has written extensively about the nitrogen cycle, reportedly asserts that "we have perturbed the global nitrogen cycle more than any other, even carbon."[56] Nearly all of the crops grown in the industrialized world, including corn and soybeans, are nitrogen-saturated, meaning they are exposed to more nitrogen than they can use.[57] Overuse of nitrogen for crops, its subsequent runoff into rivers and other bodies of water, and the millions of tonnes of nitrogen found in farm animal manure are growing threats to the environment and public health.[58]

Nitrogen pollution can adversely affect land, water, air, and, consequently, quality of life for residents of communities located near animal production facilities. The odors emanating from some factory farm manure lagoons—the pools that hold and store farm animal manure and urine—are among the most noticeable effects of nitrogen pollution. Additionally, lagoons can be fragile, leaking waste into groundwater and overflowing during rainstorms. In 1995, for example, a manure lagoon break on a pig production facility in North Carolina caused more than 20 million gallons of waste to spill into the New River, leading to a massive fish kill.[59] In 2005, a manure lagoon break at one of the largest dairy facilities in the northeast United States resulted in several million gallons of waste spilling into the Black River, killing more than 375,000 fish.[60]

Nitrogen's impacts can also be more subtle, yet extremely dangerous. Nitrous oxide, for example, persists in the atmosphere for up to 150 years and raises two significant concerns. In addition to its GWP, N_2O is involved in the depletion of the ozone layer and is present in far greater quantities than ever before, with its concentration in the atmosphere now 16% larger than in 1750.[61]

Ruminants, including cattle, goats, buffalo, and sheep, produce nitrous oxide emissions when their manure and urine are deposited. Seventy percent of anthropogenic N_2O emissions come from crop and farm animal production, with animal agriculture accounting for 65% of global N_2O emissions.[62]

Scientists from the National Center for Atmospheric Research (NCAR) and the Climate Change and Carbon Management program at Lawrence Berkeley National Laboratory seem to agree that global warming and climate change cannot be adequately addressed without paying attention to nitrogen's role. As NCAR Senior Scientist Elizabeth Holland has reportedly stated, "The changes to the nitrogen cycle are larger in magnitude and more profound than the changes to the carbon cycle…But the nitrogen cycle is being neglected."[63]

The co-chairs of the Third International Nitrogen Conference in 2004 specifically identified the role of animal-based food production in the Nanjing Declaration on Nitrogen Management, which was presented to the UN Environment Programme (UNEP). One point of agreement encompassed in the Declaration was the recognition that "a growing proportion of the world's population consumes excess protein and calories, which may lead to human health problems. The associated production of these dietary proteins (especially animal products) leads to further disturbance of the nitrogen cycle."[64]

Methane, Nitrous Oxide, and Manure Management

Each year, farm animals produce billions of tonnes of manure worldwide. In the United States alone, cattle, pigs, chickens, turkeys, and other animals raised on factory farms generate approximately 454 million tonnes of solid and liquid waste.[65]

When used to fertilize crops, manure enriches the soil and is a key input to healthy, sustainable farms and landscapes. The quantities of manure produced on factory farms, however, exceed the amount of land available to absorb it, transforming manure from a valuable agricultural resource into hazardous waste that threatens soil, water, and air quality.[66]

Storing and disposing vast quantities of manure can produce anthropogenic methane and nitrous oxide emissions.[67] According to the Pew Center on Global Climate Change, farm animal manure management currently accounts for 25% of agricultural methane emissions in the United States and 6% of agricultural nitrous oxide emissions.[68]

As noted above, methane has 23 times the GWP of carbon dioxide, and its concentrations have increased by approximately 150% since 1750. Globally, farm animals are the most significant source of anthropogenic methane, responsible for 35-40% of methane emissions worldwide.[*69]

The amount of methane produced by animals and their manure is largely determined by the animals' feed quality, digestive efficiency, body weight, age, and amount of exercise.[70,71] Ruminants emit methane during digestion,[72] which involves microbial (enteric) fermentation of fibrous feeds and grains.[73] This digestive process enables cattle, goats, buffalo, sheep, and other ruminants to consume plants that monogastric animals are unable to digest. Ruminant animals naturally consume grass and forage; however, when they are fed a low-fiber, corn-based diet, fermentation acids can accumulate in the animal's rumen,[74] the first stomach.

The standard diet of most industrial farm animal production systems is comprised of highly unnatural rations of concentrated, high-protein feeds made from corn and soybeans. For ruminants, eating corn and soybeans does not come naturally. For cattle in particular, the effects of a grain-fed diet can be devastating. Although cattle can gain weight quickly on this diet,[75] grain consumption can cause a range of illnesses[76,77] and possibly more methane emissions.[71]

Cattle confined in feedlots, for example, are fed a very high-energy grain diet, contributing to manure with a "high methane-producing capacity," whereas cattle raised on pasture, eating a low-energy diet of grasses and other forages, may produce manure with roughly 50% of the methane-producing potential of animals raised in feedlots.[78]

An additional consideration when comparing GHG emissions from various feedstuffs is the difference in CO_2 production. For example, the production of 1 kg (2.2 lb) of concentrated feed may yield 0.57-2.21 kg (1.26-4.87 lb) of CO_2,[79] which is likely higher than that produced by most forages.[80]

Increasing the digestibility of pasture for grazing ruminants may be an expedient way of reducing methane emissions from enteric fermentation, but this measure must also be accompanied by a reduction in animal numbers.[80,81] The European Environment Agency has echoed this sentiment, stating that the "main driving force of CH_4 emissions from enteric fermentation is the number of cattle."[82]

---

[*] There are also natural sources of methane, including wetlands, non-wetland soils, termites, oceans, and freshwater bodies. (U.S. Environmental Protection Agency. 2006. Where does methane come from? http://www.epa.gov/methane/sources.html. Accessed April 23, 2008.) .

Some 86 million tonnes of methane are released annually from enteric fermentation alone. In 2004, estimates for methane emissions from enteric fermentation totaled 21.17 million tonnes in Central and South America, roughly 12 million tonnes in India, and nearly 9 million tonnes in China. The rest of Asia was responsible for just over 8 million tonnes.[83]

Individual animals produce very little methane. For example, an adult cow emits 80-110 kg (176-243 lb) of methane annually.[84] Yet, together, the more than 1 billion ruminants raised worldwide every year[25] are a significant methane source. In Africa, for example, methane emissions from enteric fermentation rose from 190 Teragrams (Tg) CO_2-equivalent per year in 1990 to 222 Tg CO_2-equivalent per year in 2000 "because of a 17% increase in the ruminant population."[27] Pigs, chickens, and other monogastric farm animals, as well as humans, also produce methane during digestion, but in much smaller quantities than cattle and other ruminants.

According to the U.S. Environmental Protection Agency (EPA), animal agriculture is a major source of methane emissions in the United States.[85] Domestically, cattle raised for beef and milk production emit approximately 5.5 million tonnes[85] of methane per year into the atmosphere, which amounts to 71% of all agricultural methane emissions and 19% of the nation's total methane emissions.[84,86]

While some of these emissions result from enteric fermentation, methane is also emitted from manure. The newest estimates from the FAO show that pig production contributes the largest share of emissions from manure, followed by dairy operations. Methane emissions from pig manure represent nearly half of total global farm animal manure emissions. China has the largest country-level methane emissions in the world with 3.84 million tonnes; western Europe produces 4.08 million tonnes, North America 3.39 million tonnes, and Central and South America 1.41 million tonnes. Methane released from animal manure totals nearly 18 million tonnes annually worldwide.[87]

The 15-year period of 1990 to 2005 saw dangerous rises in GHG emissions in the United States. Methane emissions from pig and dairy cow manure increased by approximately 37% and 50%, respectively—an elevation caused by the shift towards rearing pigs and cows in larger facilities where liquid manure management systems that promote anaerobic conditions, or those in which oxygen is not present, are increasingly used. The U.S. poultry industry's shift toward litter-based manure management systems, confinement in high-rise houses, and an overall increase in the U.S. poultry population contributed to a 10% rise in nitrous oxide emissions.[67]

Under anaerobic conditions, methane and nitrous oxide are released when bacteria digest animal waste. Most of this methane comes from large, open-air lagoon or holding tank systems where farm animal waste is stored, which were developed in the 1960s to manage waste.[88] As industrial methods of pig production become the standard worldwide, methane emissions from lagoons and manure are likely to increase.

China is the world's largest producer and consumer of pork, with tens of thousands of factory farms. According to the Woodrow Wilson Center's China Environment Forum, the country's intensive farm animal production facilities produce 3.4 times the solid waste of industrial factories. As China's meat production grows, developing methods of utilizing manure and limiting GHGs will be especially important.[89]

Manure that is not stored or managed in lagoon systems, but utilized in a dry form such as in stacks or drylots for fertilizer on fields, does not produce significant amounts of methane.[83,90] Storage of manure under anaerobic conditions—like those present in lagoons—will produce large amounts of methane but suppress nitrous oxide emissions. In contrast, composting and piled storage of manure will promote aerobic decomposition, increasing nitrous oxide emissions while suppressing methane emissions.[68]

Piled storage is frequently used on smaller farms and in feedlots confining cattle raised for beef. In addition to applying manure at rates based on crop needs, another method of reducing nitrous oxide emissions is to increase the ratio of bedding material, such as straw or sawdust, to manure in systems that stockpile or compost manure.[68]

Changing the Landscape: GHG Emissions from Deforestation, Land Degradation, Soil Cultivation, and Desertification

Land uses are continually changing. Around the world, animal agriculture is often an important source of these changes.[23] Indeed, farm animals and meat, egg, and dairy production facilities cover one-third of the planet's total surface area and use more than two-thirds of its agricultural land, inhabiting nearly every country.[91] As the number of farm animals escalates, so do their impacts on forests, soils, and ecosystems.

Farm animal production is, in fact, a major driver of deforestation, turning wooded areas into grazing land and cropland for the production of feed. According to the FAO, animal agriculture-related deforestation may emit 2.4 billion tonnes of CO_2 into the atmosphere each year.[92] Tropical forests act as carbon sinks, sequestering carbon and preventing its release into the atmosphere.[93] As animal product consumption grows, grazing land, soybean monocultures, industrial feedlots, and factory farms encroach on forests, particularly in Latin America.[94]

According to a 2004 report by the Center for International Forestry Research (CIFOR), rapid growth in the exportation of Brazilian beef has accelerated destruction of the Amazon rainforest. The total area of forest lost increased from 41.5 million hectares in 1990 to 58.7 million hectares in 2000. In just ten years, reports CIFOR, an area twice the size of Portugal was lost, most of it to grazing land.[95] "In a nutshell," says David Kaimowitz, director general of CIFOR, "cattle ranchers are making mincemeat out of Brazil's Amazon rainforests."[96] Brazil is the fourth-largest GHG emitter, largely because of agricultural burning in the Amazon, which contributes some 70% of the country's emissions.[97]

As mentioned above, animal agriculture's role in deforestation has been especially devastating in Latin America, where expansion of pasture and arable land at the expense of forests has been the most prevalent. The region is also "suffering the largest net loss of forests and resulting carbon fluxes," the releases of stored carbon from vegetation and soil into the atmosphere.[93]

In fact, in 2005 the FAO found that cattle ranching is one of the main causes of forest destruction in Latin America. The FAO predicts that by 2010, more than 1.2 million hectares of forest will be lost in Central America, while 18 million hectares of South American forest will disappear, in large part, because of clearing land for grazing cattle.[98]

According to a 2008 report by Amigos da Terra Brasil (Friends of the Earth Brazil) entitled "The Cattle Realm: A New Phase in the Livestock Colonization of the Brazilian Amazonia," the World Bank and its partner, the International Finance Corporation (IFC), are reportedly funding much of the deforestation currently taking place in the Amazon.[99] Although the World Bank has reportedly pledged publicly to reduce deforestation by compensating countries that maintain and preserve their forests, they are also funding industrial slaughter plants in the Amazon basin[99]—slaughter plants that have reportedly helped ranching in the region grow by almost half from 2004-2007.[100] According to a report on the "The Cattle Realm," the IFC investigated the environmental impact of increasing the number of slaughter plants in Maraba in the eastern Amazon.[99] Despite reportedly finding that just one slaughterhouse there would lead to a loss of 300,000 hectares of forest, the IFC gave $9 million USD to Brazil's biggest beef processor.[99]

Other important ecosystems are jeopardized by soy production, around 85% of which is used for animal feed.[101] Half of Brazil's soy production occurs in the Cerrado region.[101] The world's most biologically diverse savannah, the Cerrado is the size of Alaska and the second-largest major biome in Brazil.[102,103] Nevertheless, it is among the country's least protected ecosystems.[104] According to the World Wildlife Fund, the region's animal species "are competing with the rapid expansion of Brazil's agricultural frontier, which focuses primarily on soy and corn. Ranching is another major threat to the region, as it produces almost 40 million cattle a year."[102]

The Cerrado's traditional land use of extensive cattle ranching on natural pastures maintained most of the region's natural vegetation; however, changes in government policies, including credit subsidies for technological advances, have made soybean farming more profitable than extensive cattle ranching. Although the Cerrado's natural vegetation typically stores less carbon per hectare than a rainforest, land use conversion still results in biodiversity losses, increased soil erosion, and substantial carbon emissions.[105]

Soybean and corn production for animal feed is also leading to the rapid clearance of tropical forests.[106] Mato Grasso, the state that has led Brazil in both deforestation and soybean production since 2001,[107] lost approximately 36,000 km^2 (13,900 mi^2) of forest to intensive mechanized agriculture between 2001 and 2004.[107,108] In just five months, from August through December 2007, Brazil lost more than 3,200 km^2 (1,236 mi^2) of forest in the Amazon at least partly due to illegal farming and ranching, as high prices for cattle, soybeans, and corn led farmers and ranchers to plant more crops and raise more animals.[109,110] Because of this rapid deforestation, in late January 2008, Brazilian President Luiz Inácio Lula da Silva convened an emergency meeting of cabinet ministers to call for increased monitoring of the most affected regions.[110]

Converting forests to grazing area does not just lead to increased CO_2 emissions. Land use changes for animal agriculture also greatly reduce methane oxidation by soil micro-organisms such that methane is released into the atmosphere rather than being utilized. Grazing lands can even become net sources of methane when soil compaction from animal traffic limits the diffusion of gas.[92]

Like forests, soils can serve as carbon sinks. The estimated total amount of carbon currently stored in soils is 1,100-1,600 billion tonnes—more than twice the carbon in vegetation or in the atmosphere.[111] Human disturbances (primarily agriculture), however, have significantly depleted the amount of carbon sequestered in the soil. The FAO reports that the Scientific Committee on Problems of the Environment (SCOPE), an interdisciplinary group of natural and social scientists, estimates that 50% of carbon in soils on the North American Great Plains has been lost over the last century due to burning, erosion, harvesting, grazing, or by vaporizing into the air.[111] The FAO estimates that animal agriculture-related releases from cultivated soils worldwide may total 28 million tonnes of CO_2 annually.[111]

In particular, conventional tillage practices (scraping the soil with machinery) both lower the organic carbon content of the soil and produce "significant" CO_2 emissions. The FAO estimates that an annual influx of some 18 million tonnes of CO_2 results from cultivating approximately 1.8 million km^2 (694,984 mi^2) of arable land with corn, soybean, and wheat to feed animals raised for meat, eggs, and milk.[111]

The animal agriculture sector can also play a significant role in desertification, the degradation of land in arid, semi-arid, and dry sub-humid areas, which is caused primarily by human activities and climatic variations.[112] Desertification tends to reduce the productivity and amount of vegetative cover, which then allows CO_2 to escape. The FAO estimates that animal agriculture-induced desertification of pastures releases up to 100 million tonnes of CO_2 per year.[113]

Drought, Hunger, and Conflict

The effects of climate change and global warming vary greatly by region. While the United States, Europe, and China are responsible for the greatest amounts of GHG emissions, these regions will likely not be the most affected. The majority of climate experts agree that the impoverished will be hit hardest by climate change, including farmers and small-scale farm animal keepers in the developing world. The IPCC predicts that those areas already in drought will become even drier, adding to risks of both hunger and disease, and the world will face heightened threats of flooding, severe storms, and the erosion of coastlines.[12]

For the nearly 2 billion people worldwide who rely on farm animals to support part or all of their daily needs for food, clothing, shelter, and income and the almost 200 million people who depend on grazing animals as their only source of livelihood,[114] the rising risks of drought, animal disease, and other serious problems that result from climate change will be devastating. The poorest of the poor tend to live in high-risk areas, such as coasts, and are less able to withstand the effects of climate change on water supplies or food sources.[12] Communities reliant on subsistence farming will be among the hardest hit. "Studies have consistently shown," says Robert Watson, former chair of the IPCC and now a senior scientist with the World Bank, "that agricultural regions in the developing world are more vulnerable, even before we consider the ability to cope."[115]

In the United States, it is much easier for farmers to endure a climatic setback than in poor nations such as Malawi, where approximately 40% of the economy is supported by rain-fed agriculture.[116] Henry Miller of Stanford University has reportedly said that "like the sinking of the Titanic, catastrophes are not democratic…A much higher fraction of passengers from the cheaper decks were lost. We'll see the same phenomenon with global warming."[117]

Drought will bring obvious human suffering. According to the IPCC, by 2020, up to 250 million people may experience water shortages and in some African nations, food production could fall by half.[12] The IPCC also warns that warming temperatures could result in food shortages for 130 million people across Asia by 2050. The report suggests that a 3.6°C (6.5°F) increase in mean air temperature could decrease rain-fed rice yields by 5-12% in China. In Bangladesh, says the IPCC, rice production could fall approximately 10% and wheat by one-third by 2050.[118] Temperature warming in the Himalayas could drive yak to higher elevations where there is less grass and fodder.[119]

As grazing areas dry up in sub-Saharan Africa, pastoralists will be forced to travel farther to find food and many animals will likely starve. In particular, cattle, goats, camels, sheep, and other animals who depend on access to grazing areas for food will suffer from hunger and dehydration.[120] The increased use of unsustainable agriculture, including some farm animal production methods and attendant land use changes, will likely exacerbate the effects of climate change.

Conflicts among pastoral communities are also likely to rise along with temperatures. As water supplies dry up, farmers and herders are living out an ancient struggle over land and water resources. One startling example is in Sudan's Darfur region. There, the effects of climate change and population growth, including dwindling water supplies and diminishing arable land, have created an untenable and devastating situation. Farmers and herders have taken up arms, fighting to gain and maintain control of increasingly scarce water and land.[121]

A 2007 report by the UNEP cites environmental degradation as a catalyst for the ongoing conflicts in Darfur and other parts of Sudan. Among its critical concerns are land degradation and desertification, which are tied to increases in farm animal populations: "Vulnerability to drought is exacerbated by the tendency to maximize livestock herd sizes rather than quality…In addition, an explosive growth in livestock numbers—from 28.6 million in 1961 to 134.6 million in 2004—has resulted in widespread degradation of the rangelands."[122] An almost unprecedented scale of climate change in the region is also a source of conflict due to the stress its effects impose on communities whose livelihoods depend on agriculture.[122]

Not confined to Sudan, these same battles are being fought with greater frequency in several other African nations, including Chad and Niger.[121] UN Secretary-General Ban Ki-moon has cited climate change as one factor that led to the Darfur conflict[123] and also reportedly stated that "the danger posed by war to all of humanity—and to our planet—is at least matched by the climate crisis and global warming," noting that global warming can lead to natural disasters, trigger droughts, and cause other changes that "are likely to become a major driver of war and conflict."[124]

The Spread of Disease

Some of the environmental problems caused by deforestation and industrial agriculture not only exacerbate the impacts of climate change, but are also likely promoting the spread of disease. The World Health Organization's (WHO's) coordinator for zoonoses control has been quoted saying that "[t]he chief risk factor for emerging zoonotic diseases is environmental degradation by humans, particularly deforestation, logging, and urbanisation."[125] As forests are cut down to make room for fields of soybeans, logging, and other industries, viruses may exploit such newly exposed niches.[126]

Scientists at the Harvard Medical School Center for Health and the Global Environment and the U.S. Department of Energy's Lawrence Berkeley National Laboratory predict that changes in global temperature could also lead to an increased rate of infectious disease emergence and reemergence.[127] Rift Valley fever, for example, reemerged in Kenya in late 2006, reportedly infecting 684 people, of whom 155 died.[128] Spread by mosquitoes, the fever could become more widespread as climate change increases rainfall in some areas.

Steve Sloan, chief executive of GALVmed, an organization that aims to reduce poverty for farm animal keepers in developing countries by improving their access to pharmaceuticals and vaccines for animals, has noted that insect-borne diseases, such as the viral infection bluetongue disease that was once only a threat in Africa, have hit cattle and sheep in Belgium, France, Germany, and the Netherlands. In an interview with Reuters, Sloan reportedly stated, "These 'African' diseases have become global issues because of climate change."[129]

Most pastoralists and farm animal keepers in the developing world are ill-equipped to deal with current disease problems affecting farm animals, much less those aggravated by climate change. The lack of veterinary care in some of the world's poorest and most rural areas means that communities have no assistance when the animals become sick. In addition, programs to train paravets—community members who learn how to spot health issues and treat animals—tend to receive very little funding.[130,131]

Mitigating the Animal Agriculture Sector's Role in Climate Change

Direct and immediate actions are required to mitigate and prevent the problems associated with climate change. For example, a temperature rise exceeding about 3.5°C (6.3°F), says the IPCC, could result in the extinction of 40-70% of the world's assessed species.[132] Such a rise in temperatures and their devastating impacts are inevitable, however, if we continue "business as usual."[133] Producers, consumers, and policy makers in the United States and throughout the world must examine and respond to the contributions of today's meat, milk, and egg production to GHG emissions and climate change.

Transforming Agriculture

To date, most mitigation and prevention strategies to reduce GHG emissions from animal agriculture have focused on technical solutions, such as increasing the efficiency of farm animal production and feed crop agriculture. Researchers at several universities are investigating the possibility of reformulating ruminants' diets with new feeds to reduce enteric fermentation and consequent methane emissions. One such remedy is a fist-sized, plant-based pill that, along with a special diet and strict feeding times, is intended to reduce the methane produced by cattle.[134] Winfried Drochner, the lead researcher on this supplement, believes that by reducing excessive fermentation and regulating the metabolic activity of rumen bacteria, beef and dairy producers can reduce the amount of methane emissions from both the cattle themselves and their manure.[135]

One suggested mitigation strategy to control GHG emissions from beef production is to shorten intervals between calving by one month. While this may result in less animal waste and less required feed, as cows would birth the same number of calves in a shorter amount of time and be culled at an earlier age,[51] it would likely impose additional physical stress on the animals and impair their welfare.

Another technical mitigation strategy reportedly being adopted by some large-scale producers is the use of anaerobic digesters to isolate the methane from farm animal manure and use it to power generators on-site or sell the energy to local electric companies.[136] The EPA estimates that anaerobic digestion systems are feasible at approximately 7,000 pig and dairy operations in the United States and, through the AgStar program and the Methane to Markets Partnership, provides technical assistance and financial incentives to encourage the use of these systems both domestically and globally.[137,138]

According to the EPA, existing systems provide enough renewable energy to power more than 20,000 average U.S. homes and have reduced annual methane emissions by about 1.5 million tonnes of CO_2-equivalent.[137] In 2007, the USDA agreed to contribute $1.5 million USD towards manure digester projects at three operations in Ohio, which respectively confine 580,000 chickens, 10,000 beef cattle, and 3,800 dairy cows.[139] Projects in development in Southeast Asia, aided by the World Bank and EPA, are estimated to prevent annual emissions of 4,536 tonnes of CO_2-equivalent per 20,000 pigs.[140]

Despite their benefits for mitigating GHG emissions, anaerobic digesters are not entirely risk-free. An article in the American Association of Insurance Services' magazine *Viewpoint* notes that methane from manure piped into a tank for storage essentially renders the operation "a flammable gas compressor station like that found in the natural gas industry" that, for underwriting purposes, "should be treated similarly to that of a hazardous petrochemical manufacturing plant."[138]

In addition, this technology is more likely to benefit larger operations than smaller-scale farms. According to *EnergyBiz Insider*, "Typically, a minimum herd of 300 dairy cows or 2,000 swine is needed to make such a system feasible."[141] A representative of Microgy, a New Hampshire-based company that operates renewable gas facilities using anaerobic digestion of animal and food industry waste,[142] reportedly echoes the benefits this technology offers to large-scale producers: "[T]he market is really unlimited. It's only limited by how many cows and hogs you have in feedlots."[141]

One Swedish company, Svenska Biogas, is going one step further and extracting residual methane from slaughter plant waste such as cows' stomachs, intestines, udders, livers, kidneys, and blood. Depending on the size of the animal, the company can extract 80-100 kg (176-221 lb) of methane. Annually, the company is making use of 54,000 tonnes of this waste from cows, pigs, and chickens.[143]

At least two major animal agribusiness corporations are hoping to offset their GHG emissions by joining the Chicago Climate Exchange. The Exchange is the world's first and North America's only voluntary, legally binding GHG emissions registry, reduction, and trading program. Smithfield Foods, the world's largest pig producer, and agribusiness giant Cargill both joined the Exchange in 2007.[144,145] Smithfield and Cargill have each committed to cutting their GHG emissions by a minimum of 6% by 2010.[144,145]

Like carbon trading programs, carbon offsets allow companies and other emitters to invest in measures to reduce emissions elsewhere or to engage in other actions to prevent, sequester, or displace CO_2 emissions in order to compensate for their own emissions.[146,147] Criticisms of offset programs abound, chief among them being the idea that, in some instances, they may only be symbolic, rewarding emitters for measures that would have been taken despite participation in an offset program.[148,149]

Smithfield plans to achieve its goal by investing more resources in biogas collection. At its Tar Heel pig slaughtering plant in North Carolina, for example, Smithfield is using methane generated by its wastewater treatment system as boiler fuel. In Michigan, the company is burning methane from a 10 million-gallon anaerobic manure lagoon in place of using natural gas energy. Two of the company's other facilities are also making biofuels out of animal fats and oils.[144]

Seaboard Foods, one of the nation's top-ten pig producers,[150] is using animal fats to create biodiesel and has even created a corporate subsidiary, High Plains Bioenergy, to manage these efforts.[151] Tyson Foods has teamed up with oil giant ConocoPhillips and Syntroleum, a fuel technology company, to create renewable diesel using fats from beef, pork, and poultry byproducts. Production is expected to yield as much as 662-946 million liters (175-250 million gallons) per year.[152,153] The companies claim their renewable diesel meets all federal standards for ultra-low-sulfur diesel.[152]

To address emissions from deforestation, the international environmental organization Greenpeace reportedly worked with the McDonald's Corporation to pressure the largest soy traders in Brazil to observe a two-year moratorium on the purchase of any soy from newly deforested areas.[154] Cargill, the multinational company that was supplying McDonald's with Brazilian soy to be used as chicken feed, assisted in persuading fellow soy traders to agree to the moratorium. As one Cargill official reportedly noted, "The moratorium will give everyone time to plan how to better control the farming and protect the forest."[154]

Ironically, McDonald's Japanese division has used one of its products as an incentive to encourage customers to combat global warming. In a joint program with Japan's Ministry of the Environment in September 2007, the company reportedly offered half-priced Big Macs to customers who simply pledged to reduce their CO_2 emissions by checking up to 39 boxes on a form listing various suggested strategies.[155]

Developing feedlot rations to reduce emissions from enteric fermentation, using animal waste and carcasses to generate fuel, and selectively purchasing feed crops from less devastated forested regions may be innovative ways of reducing GHG emissions; however, these strategies do little to address the environmental problems inherent in industrialized meat, egg, and milk production.

The IPCC's Saleemul Huq reportedly insists that "[a]daptation is the only option in the short term."[156] Even if no more carbon is put into the atmosphere, which is highly unlikely, average warming of 0.6°C [1°F] can evidently still be expected over the rest of this century. Over the longer term, Huq is quoted as saying that "the only solution" for climate change "is to do mitigation now. If we fail to do either of them now we will suffer."[156]

Still, the FAO claims that larger factory farm operations have a greater ability to adapt to the ravages of climate change than small, backyard, and extensive systems. The authors of "Livestock's Long Shadow" assert, "In general, intensively managed livestock systems will be easier to adapt to climate change than will crop systems." According to the FAO, extensive systems, where animals are raised outdoors, will not be able to adapt to climate change as readily because they are more susceptible to changes in climate and both the severity and distribution of farm animal diseases and parasites, which may result from global warming.[157] Yet evidence from small farms around the world suggests a different scenario.

Small communities in the developing world, particularly throughout Africa, have been adapting to climate fluctuations, including extreme droughts, for decades. In addition to planting crops farther apart so that more water is available to each row, farmers are investing more in rearing animals, particularly species who have been bred to withstand harsh climates.[158] Nguni cattle in South Africa, for example, have a high level of heat tolerance and the Mukhatat chicken of Iraq can withstand harsh environmental conditions.[159,160]

Today's industrial genetic selection for varied production-enhancing traits, however, can adversely impact animal welfare, so these measures may not only be unsustainable, given the growing effects of climate change, but may also cause greater animal suffering.[161] The FAO's "State of the World's Animal Genetic Resources" report underscores the need to protect global farm animal diversity and the characteristics unique to certain breeds that may help in adapting to climate change.[26]

Most agricultural experts agree that farms that do not rely exclusively on corn, soybeans, or one species of animal will withstand the pressures of climate change better than less diverse farms. Indeed, by diversifying, planting and raising a range of crops, and rotationally grazing animals in extensive systems, farmers can resist a wider range of shocks and become less dependent on outside inputs, such as petroleum. According to a study published in *Bioscience*, "[p]asture-raised animals require less fuel for operations and less feed than do confined animals." In addition, these systems could "tie up 14 million to 21 million metric tons of CO_2 and 5.2 million to 7.8 million metric tons of N_2O in the organic matter of pasture soils."[162]

The Land Institute's Sunshine Farm Project in Kansas raises crops without fossil fuels, artificial fertilizers, or pesticides to reduce its contributions to climate change. The farm raises most of its feed, including oats, grain sorghum, and alfalfa, for the animals reared there, and manure and leguminous crops in the crop rotation substitute for energy-inefficient nitrogen fertilizers. A 4.5-kilowatt photovoltaic array powers the farm's tools, electric fencing, water pumps, and the light needed for chick brooding.[163]

In addition, production systems that rely on grasslands or crop residues for feed usually have very low or even negligible fossil-fuel use. In many developing countries, particularly in Asia and Africa, animals are an important source of power for pulling plows and running other machinery, which, says the FAO, is "a CO_2 emission avoiding practice."[21]

Organic agriculture systems have the potential to reduce GHG emissions and sequester carbon, as concluded in a study commissioned by the International Federation of Organic Agriculture Movements. In contrast with conventional animal agriculture, organic farming reduces nitrous oxide emissions by feeding dairy cows diets that are lower in protein and higher in fiber, and by avoiding overproduction of manure by limiting animal stocking densities to the land available for manure application. Organic agriculture also uses less fossil fuel energy, in part because "external animal feeds—often with thousands of transportation miles—are limited to a low level."[164]

Organic agriculture also has greater potential to foster biodiversity than conventional agricultural systems, which rely on an array of pesticides, herbicides, and other agro-chemicals. Organically managed agricultural land tends to be more bio-diverse, supporting a range of grasses and species, including songbirds, earthworms, and soil microorganisms.[165]

Some studies have suggested that the production of organic beef, with cattle raised on grass rather than on concentrated feed, may emit as much as 39% less GHGs in CO_2 equivalents and consume 85% less energy than conventionally produced beef.[51,166]

Some researchers have noted the ostensible resource efficiency of non-ruminant farm animals like chickens, who require less feed, water, and land than ruminants. While it is true that chickens and pigs generate lower emissions per unit of product, their production still has significant environmental impacts because of the emissions from their manure, as well as the production and transport of grain to provide their feed.[167]

Accountability of Policy Makers

Governments must better regulate the GHG emissions from industrialized animal operations. The U.S. Supreme Court declared in April 2007 that the EPA has the authority to regulate carbon dioxide and other heat-trapping emissions from vehicles as pollutants.[168,169] The same regulations should be in place for other sectors—including animal agriculture—that emit GHGs into the atmosphere. Such policies will require greater and better monitoring of large animal-feeding operations, as well as moratoriums on the construction of new farm animal production facilities.

One important step will be accurately pricing environmental services, such as a stable climate and clean air, and animal agriculture experts at FAO agree. "Most frequently natural resources are free or underpriced, which leads to overexploitation and pollution," write the authors of "Livestock's Long Shadow," concluding that "[a] top priority is to achieve prices and fees that reflect the full economic and environmental costs, including all externalities."[170]

Similar criticisms have been voiced by New Zealand's Green Party. Jeanette Fitzsimons, co-leader of the national party, has argued that the country's focus on growing the dairy industry has come at the expense of the environment. Advocating the use of financial penalties to advance more environmentally sound production practices, she reportedly adds, "We need charges on pollution, most urgently on greenhouse gases."[171]

The authors of "Livestock's Long Shadow" call attention to the need to establish accurate pricing within the animal agriculture sector "by selective taxing of and/or fees for resource use, inputs and wastes."[172] Such a system could include developing fair pricing of environmental services, such as forests and biodiversity, so logging to make land available for grazing cattle or cultivating feed crops is not the only viable financial option for ecologically fragile regions.

Consider the following example from Costa Rica: According to a 2004 study published in the *Proceedings of the National Academy of Sciences*, pollination services provided by native bees inhabiting the forest near a coffee plantation total $62,000 USD. In other words, the bees from a nearby forest provide a valuable economic resource that, until now, had not been quantified. The researchers found that if the forest were used for other purposes, the value would be much less. For example, if farmers chose to cut down the trees to raise cattle, the total value of that land would be $24,000 USD, two-thirds less than what the forest-dwelling bees provide.[173]

The Kyoto Protocol, an amendment to the UN Framework Convention on Climate Change (UNFCCC), was established in 1997 and came into force in 2005. Although most of the nations in the world have ratified the protocol, the United States has not.[174,175] The Protocol's principal component is the establishment of mandatory targets on GHG emissions for the world's leading economic powers that have chosen to ratify it.[176]

Under Kyoto, nations can buy and sell GHG emissions and credits through emissions trading, creating a carbon market whereby nations with fewer emissions can sell their offsets to those who produce more emissions. The UNFCCC notes that the "price may be steep" for countries not meeting their commitments. The higher the cost, says UNFCCC, the more pressure those nations will feel to use energy more efficiently and to research and promote the development of alternative sources of energy that have low or no emissions.[177]

According to Amazonian botanist Sir Ghillean T. Prance, "[o]ne of the disappointing flaws of the Kyoto Protocol…is that its system of carbon credits does not give credit for avoided deforestation, reforestation, and afforestation."[178] Sir Prance advocates a more comprehensive approach, including countries in the developed world compensating developing countries for creating protected areas of forest and financing reforestation and afforestation, as well as establishing a carbon credits system for reforestation and afforestation.[178]

The Forests Now Declaration, endorsed by more than 200 conservationists, NGOs, scientists, and business leaders, calls on governments "to take urgent action on deforestation in the tropics and sub-tropics, which causes 18-25% of global carbon emissions, more than the world's entire transport industry."[179] Noting that deforestation is driven by demands for a handful of commodities, including soy and beef,[179] the Declaration recommends a number of actions. Among them are the inclusion of credits for reduced emissions from deforestation and the protection of standing forests in carbon markets, particularly those created by the UNFCCC.[180]

Another important feature of Kyoto is its Clean Development Mechanism. Kyoto does not limit the amount of GHGs from developing nations. However, under this mechanism, industrialized countries can sponsor projects in poorer nations that reduce or avoid emissions. These nations are also awarded credits that can be applied to meeting their own emissions targets, which allows poorer nations to benefit from a free influx of advanced technology to curb GHG emissions from their factories and power plants—and, optimally in the near future, their animal agriculture operations. New options within the program are also being considered,[181] including reforestation projects that, optimally, would help to dissuade beef and grain producers from rearing animals or farming crops in fragile rainforests.

Kyoto, however, expires in 2012.[182] In December 2007, negotiators met in Bali, Indonesia, to begin making preparations for a post-Kyoto world.[183] The Bali Action Plan, or Bali Roadmap, calls for a number of actions to curb climate change,[184] including the strengthening of the "Adaptation Fund." This Fund, although discussed under Kyoto, is meant to finally provide adequate funding to developing nations to implement their own mitigation and adaptation programs to fight climate change.[184] Another important step taken by negotiators in Bali is development of a strategy to reduce deforestation in developing countries. The agreement strengthens reforestation efforts and calls for better technical assessments of deforestation and resulting GHG emissions.[185]

In addition to observing the terms of the Kyoto and Bali agreements, leaders can begin developing their own national policies for emissions reductions. One innovative policy under discussion, Zero Carbon Britain, suggests a new "carbon economics" that will raise both the price and transport of conventional agro-chemical-based food products. As a result, organic and local food production—which have lower emission costs—will become both an environmental and economic necessity. The report also found that "carbon economics" will motivate a large reduction in livestock, by 60% or more.[186] Most importantly, there will be a "rapid decline" of industrial pig and poultry farms, with a shift to more local and free-range systems.[167] While such a plan will likely not work in every country or community, it shows that thinking creatively about making animal and crop agriculture more sustainable can have a range of benefits.

Other regional and national policy choices, including those that provide "safety nets" for producers or that reward farmers for diversifying crop and animal production, should also be supported. Encouraging hay production and the growth of pastures in the Midwestern United States, for example, would allow more farmers to raise ruminant animals on grass instead of feeding them grain.[187]

Making Climate-Friendly Food Choices

As consumers become increasingly concerned about climate change and global warming, they are choosing more environmentally friendly products, such as energy-efficient appliances, compact fluorescent light bulbs, solar panels, and hybrid vehicles. While these are all important measures toward increasing energy efficiency and curbing GHG emissions, choosing more sustainably produced meat, eggs, and milk, as well as replacing and reducing animal product consumption are also very effective strategies for mitigating the impacts of climate change.

One new resource available to consumers is Climate Counts, a non-profit organization that encourages individuals to consider the carbon footprint of goods and services[188] when making purchasing decisions. Climate Counts allows people to see how companies have contributed to climate change, as well as what they are doing to reduce GHG emissions. Sixty companies are ranked from zero to one hundred.[189] Of the 17 food and food service companies on the site, none scored higher than Unilever with 71.[190,191] Even Stonyfield Farm, purveyors of organic yogurt and milk, only scored 63.[190] Burger King and Wendy's International each received a 0 ranking, while McDonald's was reportedly pleased with its ranking of 22.[191,192] Bob Langert, McDonald's Vice President for Corporate Social Responsibility, reported to *The New York Times* that the corporation reduced energy use in its domestic restaurants by 4% in 2006 and will begin ranking its own suppliers on their "environmental activities."[192]

By choosing to support local producers, consumers can help to reduce food miles (the distance between where food is raised and where it is eaten) and, thus, reduce the energy it takes to transport food from place to place.[193] This commitment to minimizing food transport is being embraced by some retailers who are beginning to label products based on their carbon-friendliness. Tesco, the largest supermarket chain in Britain and one of the top five in the world, reportedly hopes to reduce its customers' carbon footprints by labeling all 70,000 products in its stores with information about how the food was produced and how far it was transported.[194]

Replacing meat, eggs, and dairy products with plant-based foods—even by simply incorporating more animal-free foods into one's diet—is also an effective strategy to reduce GHG emissions from animal agriculture and address its other harmful impacts. A 2007 article in the *European Journal of Clinical Nutrition* notes that "vegetarian and vegan diets could play an important role in preserving environmental resources and in reducing hunger and malnutrition in poorer nations."[28] Similarly, a 2007 position paper by the American Dietetic Association states that dieticians "can encourage eating that is both healthful and conserving of soil, water, and energy by emphasizing plant sources of protein and foods that have been produced with fewer agricultural inputs."[195]

The Organic Consumers Association encourages consumers to seek out locally produced, seasonal organic foods, as well as vegetarian fare to combat climate change.[196] Environmental organizations also address this connection. For example, the Natural Resources Defense Council's monthly column on sustainable living, "This Green Life,"[197] devoted its November 2007 entry to advocating reduced consumption of meat, eggs, and dairy products to mitigate climate change, noting that "[t]he answer isn't milk in place of meat, but a more plant-based diet overall."[198] Environmental Defense devotes one page on its website to tips for "Fighting Global Warming with Food," primarily addressing the benefits of reducing meat consumption.[199] Greenpeace's online "Green Living Guide" includes a piece about the environmental impacts of meat production and suggests consumers "go vegetarian or simply cut down on the amount of animal products you consume."[200] Indeed, as *TIME* Magazine concluded in March 2007, "given the amount of energy consumed raising, shipping and selling livestock, a 16-oz. [450 g] T-bone is like a Hummer on a plate."[201]

Reducing consumption of meat, eggs, and dairy products is critical to control GHG emissions from animal agriculture and mitigate its other harmful impacts. In January 2008, IPCC Chair Rajendra Pachauri reportedly urged consumers to eat less meat to fight global warming, one among a few lifestyle changes he said the IPCC was "afraid" to advocate earlier.[202] As researchers wrote in the *American Journal of Clinical Nutrition* in 2003, "skepticism has been directed at supporting the increased demand for animal products in the diet of the economically advantaged persons of the world," noting "a direct link between dietary preference, agricultural production, and environmental degradation."[203] Human health, in addition to environmental health, also benefits from eating fewer animal products. An article published by *The Lancet* in September 2007 advocates a reduction in meat consumption to 90 g (3.18 oz) per person per day (roughly the equivalent of a single beef hamburger patty), both to reduce GHG emissions and to promote better human health. According to the authors, "the unprecedented serious challenge posed by climate change necessitates radical responses…For the world's higher-income populations, greenhouse-gas emissions from meat-eating warrant the same scrutiny as do those from driving and flying."[204]

Conclusion

Mitigating the animal agriculture sector's significant yet underappreciated role in climate change is vital for the health and sustainability of the planet, the environment, and its human and nonhuman inhabitants. As experts at the Intergovernmental Panel on Climate Change, the Food and Agriculture Organization of the United Nations, and numerous other leading global entities have identified, reducing GHG emissions is both urgent and critical. As the largest anthropogenic user of land and responsible for more GHG emissions than transportation, the farm animal production sector must be held accountable for its many deleterious impacts, and changes in animal agricultural practices must be achieved. Individually, reducing food miles and choosing less harmful transportation and energy use options are effective strategies; however, incorporating environmentally sound and animal welfare-friendly practices into daily life, including adopting consumptive habits less reliant on meat, eggs, and dairy products, are necessary to slow the effects of climate change.

References

1. U.S. Environmental Protection Agency. Climate change: basic information. www.epa.gov/climatechange/basicinfo.html. Accessed April 23, 2008.
2. Intergovernmental Panel on Climate Change. 2007. Climate change 2007: the physical science basis; summary for policymakers. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, p. 2.
3. World Meteorological Organization of the United Nations. 2007. The World Meteorological Organization reports on extreme weather and climate events. August 7. www.wmo.ch/pages/mediacentre/press_releases/pr_791_e.html. Accessed April 23, 2008.
4. National Aeronautics and Space Administration Goddard Institute for Space Studies. 2006. 2005 warmest year in over a century, January 24. www.nasa.gov/vision/earth/environment/2005_warmest.html. Accessed April 23, 2008.
5. Intergovernmental Panel on Climate Change. 2007. Fourth Assessment Report. Climate Change 2007: Synthesis Report. Summary for Policymakers, pp. 2-5.
6. U.S. Geological Survey. 2007. Future retreat of Arctic sea ice will lower polar bear populations and limit their distribution. www.usgs.gov/newsroom/article.asp?ID=1773 Accessed April 23, 2008.
7. The Associated Press. 2007. Most polar bears could die out by 2050. The Associated Press, September 8.
8. Topping JC. Summit aftermath: study by NASA and university scientists shows world temperature reaching a level not seen in thousands of years and raises grave concern of irreparable harm.

www.climate.org/2002/programs/washington_summit_temperature_rise.shtml. Accessed April 23, 2008.
9. Intergovernmental Panel on Climate Change. 2007. Climate change 2007: the physical science basis; summary for policymakers. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, p. 13-4.
10. Olivier J. 2000. Emissions inventory of natural sources. International Global Atmospheric Chemistry. IGACtivities Newsletter of the International Global Atmospheric Chemistry Project. Issue No. 22. December 2000, pp. 5-7. www.igac.noaa.gov/newsletter/22/IGACtivities_22.pdf. Accessed April 23, 2008.
11. Intergovernmental Panel on Climate Change. 2007. Climate change 2007: the physical science basis; summary for policymakers. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, p. 1-4.
12. Intergovernmental Panel on Climate Change. 2007. Climate change 2007: climate change impacts, adaptation and vulnerability; summary for policymakers. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report.
13. Intergovernmental Panel on Climate Change. 2007. Climate change 2007: climate change impacts, adaptation and vulnerability; summary for policymakers. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report, p. 9.
14. Intergovernmental Panel on Climate Change. 2007. Climate change 2007: climate change impacts, adaptation and vulnerability; summary for policymakers. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report, Chapter 5: food, fibre, and forest products.
15. Intergovernmental Panel on Climate Change. 2007. Climate Change 2007: the synthesis report; summary for policymakers. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, p. 13.
16. Nobel Foundation. 2007. The Nobel Peace Prize for 2007. October 12. http://nobelprize.org/nobel_prizes/peace/laureates/2007/press.html. Accessed April 23, 2008.
17. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 82.
18. U.S. Environmental Protection Agency. Climate change-science. www.epa.gov/climatechange/science/index.html. Accessed April 23, 2008.
19. Paustian K, Antle JM, Sheehan J, and Paul EA. 2006. Agriculture's role in greenhouse gas mitigation. Pew Center on Global Climate Change, p. 3.
20. DeCicco J and Fung F. 2006. Global warming on the road: the climate impact of America's automobiles. Environmental Defense, p. v.
21. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 90.
22. Food and Agriculture Organization of the United Nations. 2006. Livestock a major threat to environment; remedies urgently needed. November 29. www.fao.org/newsroom/en/news/2006/1000448/index.html. Accessed April 23, 2008.
23. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. xxi.
24. U.S. Department of Agriculture. 2004. U.S. agriculture and forestry greenhouse gas inventory: 1990-2001, p. 11. www.usda.gov/oce/global_change/inventory_1990_2001/USDA%20GHG%20Inventory%20Chapter%202.pdf. Accessed April 23, 2008.
25. Food and Agriculture Organization of the United Nations. FAO Statistical Database, FAOSTAT. http://faostat.fao.org/site/567/default.aspx. Accessed April 23, 2008.
26. Food and Agriculture Organization of the United Nations, Commission on Genetic Resources for Food and Agriculture. 2007. The state of the world's animal genetic resources for food and agriculture. www.fao.org/docrep/010/a1250e/a1250e00.htm. Accessed April 23, 2008.

27. Verge XPC, De Kimpe C, and Desjardins RL. 2007. Agricultural production, greenhouse gas emissions and mitigation potential. Agricultural and Forest Meteorology 142:225-69.
28. Baroni L, Cenci L, Tettamanti M, and Berati M. 2007. Evaluating the environmental impact of various dietary patterns combined with different food production systems. European Journal of Clinical Nutrition 61:279-86.
29. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 275.
30. Food and Agriculture Organization of the United Nations. Responding to the "livestock revolution": the case for livestock public policies. www.fao.org/ag/againfo/resources/documents/pol-briefs/01/EN/AGA01_10.pdf. Accessed April 23, 2008.
31. Thorne PS. 2007. Environmental health impacts of concentrated animal feeding operations: anticipating hazardssearching for solutions. Environmental Health Perspectives 115(2):296-7. www.ehponline.org/members/2006/8831/8831.html. Accessed April 23, 2008.
32. Paustian K, Antle JM, Sheehan J, and Paul EA. 2006. Agriculture's role in greenhouse gas mitigation. Pew Center on Global Climate Change, pp. 4-5.
33. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, pp. 86 and 90-92.
34. Bierbaum R, Holdren JP, MacCracken M, Moss RH, and Raven PH. 2007. Confronting climate change: avoiding the unmanageable and managing the unavoidable. Scientific Expert Group Report on Climate Change and Sustainable Development. Prepared for the 15th Session of the Commission on Sustainable Development, pp. 2-4. www.unfoundation.org/files/pdf/2007/SEG_Report.pdf. Accessed April 23, 2008.
35. Climate Institute. 2007. Climate change. www.climate.org/topics/climate-change/index.html. Accessed April 23, 2008.
36. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, pp. 272 and 85-6.
37. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 86.
38. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, pp. 86 and 48.
39. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 88.
40. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, pp. 88-9.
41. Baroni L, Cenci L, Tettamanti M, and Berati M. 2007. Evaluating the environmental impact of various dietary patterns combined with different food production systems. European Journal of Clinical Nutrition 61:279-86, citing: Moriconi E. 1997. Nutrirsi tutti, inquinando meno (Food for everyone, with less pollution). Regione Piemonte, Assessorato Tutela Ambientale (in Italian).
42. Food and Agriculture Organization of the United Nations. Draught animal power…an overview. www.fao.org/ag/Ags/subjects/en/farmpower/power/overview.html. Accessed April 23, 2008.
43. Food and Agriculture Organization of the United Nations. 2000. Draught animals plough on. www.fao.org/AG/magazine/0009sp1.htm. Accessed April 23, 2008.
44. Herold P. and Hefi J. 2000. Modern draught horse technology in organic farming, current state and significance: comparative analyses of horse drawn and tractor drawn mowers. IFOAM 2000, the world grows organic: proceedings 13th IFOAM scientific conference, p. 332.
45. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, pp.

99-100.
46. Halweil B. 2002. Home grown: the case for local food in a global market. Worldwatch Paper 163.
47. Shields DA and Mathews KH Jr. 2003. Interstate Livestock Movements. U.S. Department of Agriculture Economic Research Service. http://ers.usda.gov/publications/ldp/jun03/ldpm10801/ldpm10801.pdf. Accessed April 23, 2008.
48. Greger M. 2007. The long haul: risks associated with livestock transport. Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science 5:301-11.
49. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 100.
50. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, pp. 100-1.
51. Ogino A, Orito H, Shimada K, and Hirooka H. 2007. Evaluating environmental impacts of the Japanese beef cow-calf system by the life cycle assessment method. Animal Science Journal 78:424-32.
52. Fanelli D. 2007. Meat is murder on the environment. New Scientist, July 18, p. 15. http://environment.newscientist.com/article.ns?id=mg19526134.500&feedId=online-news_rss20. Accessed April 23, 2008.
53. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 99.
54. Personal correspondence with Vaclav Smil, University of Manitoba February 9 2008.
55. Smil V. 2000. Enriching the Earth: Fritz Haber, Carl Bosch, and the Transformation of World Food Production (Cambridge, MA: The MIT Press, pp. 156-64).
56. Pollan M. 2006. The Omnivore's Dilemma: A Natural History of Four Meals (New York, NY: The Penguin Press, p. 47).
57. Smil V. 2000. Enriching the Earth: Fritz Haber, Carl Bosch, and the Transformation of World Food Production (Cambridge, MA: The MIT Press, p. 177 and 184-186).
58. Smil V. 2000. Enriching the Earth: Fritz Haber, Carl Bosch, and the Transformation of World Food Production (Cambridge, MA: The MIT Press, pp. 188-94).
59. Ribaudo M. 2003. Managing manure: new Clean Water Act regulations create imperative for livestock producers. U.S. Department of Agriculture Economic Research Service. Amber Waves, February. www.ers.usda.gov/AmberWaves/Feb03/Features/ManagingManure.htm. Accessed April 23, 2008.
60. New York State Department of Environmental Conservation. 2006. DEC announces consent order with Lewis County farm for manure spill. www.dec.ny.gov/environmentdec/18863.html. Accessed April 23, 2008.
61. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 103.
62. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, pp. 103 and 114.
63. Bohan S. 2007. Nitrogen overdose. Oakland Tribune, August 12.
64. Zhu Z, Minami K, and Galloway J. 2004. Nanjing Declaration on nitrogen management. Presented to the United Nations Environment Programme. www.initrogen.org/fileadmin/user_upload/nanjing/nanjing_declaration-041016.pdf. Accessed April 23, 2008.
65. U.S. Environmental Protection Agency. 2003. National pollutant discharge elimination system permit regulation and effluent limitation guidelines and standards for concentrated animal feeding operations (CAFOs); Final Rule, February 12. 68 Federal Register 7176-80.
66. Gerba CP and Smith JE Jr. 2005. Sources of pathogenic microorganisms and their fate during land application of wastes. Journal of Environmental Quality 34(1):42-8.
67. U.S. Environmental Protection Agency. 2007. Inventory of U.S. greenhouse gas emissions and sinks:

1990-2005, p. 6-6. www.epa.gov/climatechange/emissions/downloads06/07CR.pdf. Accessed April 23, 2008.
68. Paustian K, Antle JM, Sheehan J, and Paul EA. 2006. Agriculture's role in greenhouse gas mitigation. Pew Center on Global Climate Change, p. 17.
69. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, pp. 82 and 112.
70. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, pp. 82, 112, and 96.
71. Paustian K, Antle JM, Sheehan J, and Paul EA. 2006. Agriculture's role in greenhouse gas mitigation. Pew Center on Global Climate Change, p. 18.
72. U.S. Environmental Protection Agency. 2006. Methane: sources and emissions. www.epa.gov/methane/sources.html. Accessed April 23, 2008.
73. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 83.
74. Clancy K. 2006. Greener pastures: how grass-fed beef and milk contribute to healthy eating, p. 13. www.ucsusa.org/assets/documents/food_and_environment/greener-pastures.pdf. Accessed April 23, 2008.
75. Radostits OM, Gay CC, Blood DC, and Hinchcliff KW. 2000. Veterinary Medicine: A Textbook of the Diseases of Cattle, Sheep, Pigs, Goats and Horses, 9th Edition (China: W.B. Saunders, p. 285).
76. Smith RA. 1998. Impact of disease on feedlot performance: a review. Journal of Animal Science 76:272-4.
77. Russell JB and Rychlik JL. 2001. Factors that alter rumen microbial ecology. Science 292:1119-22.
78. U.S. Environmental Protection Agency. 1998. Inventory of U.S. greenhouse gas emissions and sinks: 1990-1996, p. 5-5. www.epa.gov/climatechange/emissions/downloads06/98CR.pdf. Accessed April 23, 2008.
79. Howden S and O'Leary G. 1996. Evaluating options to reduce greenhouse gas emissions from an Australian temperate wheat cropping system. Environmental Modeling and Software 12:169-76.
80. O'Mara F. 2004. Greenhouse gas production from dairying: reducing methane production. Advances in Dairy Technology 16:295-309. www.wcds.afns.ualberta.ca/Proceedings/2004/Manuscripts/295OMara.pdf. Accessed April 23, 2008.
81. Lassey KR. 2007. Livestock methane emission: from the individual grazing animal through national inventories to the global methane cycle. Agricultural and Forest Meteorology 142:120-32.
82. European Environment Agency. 2007. Annual European Community greenhouse gas inventory 1990-2005 and inventory report 2007. Submission to the UNFCCC Secretariat, May 27, p. 299. http://reports.eea.europa.eu/technical_report_2007_7/en/Full%20report%20Annual%20European%20Community%20greenhouse%20gas%20inventory%201990-2005%20and%20inventory%20report%202007.pdf. Accessed April 23, 2008.
83. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 97.
84. U.S. Environmental Protection Agency. Ruminant livestock: frequent questions. www.epa.gov/methane/rlep/faq.html. Accessed April 23, 2008.
85. U.S. Environmental Protection Agency. Sources and emissions: methane. www.epa.gov/methane/sources.html. Accessed April 23, 2008.
86. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 96.
87. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, pp. 97-9.
88. Miner JR, Humenik FJ, and Overcash MR. 2000. Managing Livestock Wastes to Preserve Environmental

Quality (Ames, Iowa: Iowa State University Press, p. 150).
89. Ellis L. 2007. Environmental health and China's concentrated animal feeding operations (CAFOs); a China Environmental Health Project research brief. Woodrow Wilson International Center for Scholars.
90. U.S. Environmental Protection Agency. 2006. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004, p. 6-6. www.epa.gov/climatechange/emissions/downloads06/06_Complete_Report.pdf. Accessed April 23, 2008.
91. de Haan C, Steinfeld H, and Blackburn H. 1997. Livestock and the environment: finding a balance. Food and Agriculture Organization of the United Nations, U.S. Agency for International Development, and World Bank, p. 8.
92. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 91, citing Mosier A, Wassman R, Verchot L, King J, and Palm C. 2004 Methane and nitrogen oxide fluxes in tropical agriculture soils: sources, sinks, and mechanisms. Environment, Development and Sustainability 6(1-2):11-49.
93. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, pp. 90-1.
94. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 91.
95. Kaimowitz D, Mertens B, Wunder S, and Pacheco P. 2004. Hamburger connection fuels Amazon destruction: cattle ranching and deforestation in Brazil's Amazon. Center for International Forestry Research, pp. 1-2. www.cifor.cgiar.org/publications/pdf_files/media/Amazon.pdf. Accessed April 23, 2008.
96. Center for International Forestry Research. 2004. World appetite for beef making mincemeat out of Brazilian rainforest according to report from major international forest research center. April 2. www.cifor.cgiar.org/PressRoom/MediaRelease/2004/2004_04_02.htm. Accessed April 23, 2008.
97. Haag L. 2007. Post-Kyoto pact: shaping the successor. Nature reports climate change. Nature, June 7. www.nature.com/climate/2007/0706/full/climate.2007.12.html. Accessed April 23, 2008.
98. Food and Agriculture Organization of the United Nations. 2005. Cattle ranching is encroaching on forests in Latin America. June 8. www.fao.org/newsroom/en/news/2005/102924/index.html. Accessed April 23, 2008.
99. Howden D. 2008. World Bank pledges to save trees…then helps cut down Amazon forest. The Independent, January 13. www.independent.co.uk/environment/climate-change/world-bank-pledges-to-save-trees-then-helps-cut-down-amazon-forest-769997.html. Accessed April 23, 2008.
100. Smeraldi M and May P. 2008. The Cattle Realm: A new phase in the livestock colonization of the Brazilian Amazonia. www.amazonia.org.br/arquivos/259673.pdf. Accessed April 23, 2008.
101. World Wildlife Fund. Facts about soy production and the Basel Criteria. http://assets.panda.org/downloads/factsheet_soy_eng.pdf. Accessed April 23, 2008.
102. World Wildlife Fund. Brazilian savannas. www.panda.org/news_facts/education/best_place_species/current_top_10/brazilian_savannas_.cfm. Accessed April 23, 2008.
103. Klink CA and Machado RB. 2005. Conservation of the Brazilian Cerrado. Conservation Biology 19(3):707-13.
104. Fearnside PM. 2001. Soybean cultivation as a threat to the environment in Brazil. Environmental Conservation 28(1):23-38.
105. Kaimowitz D and Smith J. 2001. Soybean technology and the loss of natural vegetation in Brazil and Bolivia. In: Angelsen A and Kaimowitz D (eds.), Agricultural Technologies and Tropical Deforestation (Bangor, Indonesia: CABI Publishing, pp. 195-211).
106. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 12.
107. Morton DC, DeFries RS, Shimabukuro YE, et al. 2006. Cropland expansion changes deforestation

dynamics in the southern Brazilian Amazon. Proceedings of the National Academy of Sciences 103(39):14637-41.
108. Ramalho M. 2006. Crops responsible for deforestation in Brazil. Science and Development Network, September 5. www.scidev.net/News/index.cfm?fuseaction=readNews&itemid=3081&language=1. Accessed April 23, 2008.
109. BBC News. 2008. Brazil Amazon deforestation soars. BBC News. http://news.bbc.co.uk/2/hi/americas/7206165.stm. Accessed April 23, 2008.
110. Sibaja M. 2008. Brazil to increase monitors in rain forest as illegal clearing spreads. www.washingtonpost.com/wp-dyn/content/article/2008/01/24/AR2008012401059.html. Accessed April 23, 2008.
111. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 92.
112. Food and Agriculture Organization of the United Nations. Desertification. www.fao.org/desertification/default.asp?lang=en. Accessed April 23, 2008.
113. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. 93.
114. Anderson S. 2003. Animal genetic resources and livelihoods. Ecological Economics 45(3):331-9.
115. Halweil B. 2005. The irony of climate. World Watch Magazine, March/April.
116. Menin R. 2007. Human Development Report 2007/2008. Fighting climate change: Human solidarity in a divided world. Famine in Malawi: Causes and consequences. United Nations Development Program. http://hdr.undp.org/en/reports/global/hdr2007-2008/papers/menon_roshni_2007a_malawi.pdf. Accessed April 23, 2008.
117. Revkin A. 2007. Poor nations to bear brunt as world warms. The New York Times, April 1.
118. Casey M. 2007. Millions face hunger from climate change. The Associated Press, April 10.
119. Food and Agriculture Organization of the United Nations. 2007. Adaptation to climate change in agriculture, forestry and fisheries: perspective, framework and priorities, pp. 15-6. ftp://ftp.fao.org/docrep/fao/009/j9271e/j9271e.pdf. Accessed April 23, 2008.
120. Intergovernmental Panel on Climate Change. 2007. Climate change 2007: climate change impacts, adaptation and vulnerability; summary for policymakers. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report, Chapter 5: food, fibre, and forest products, pp. 275 and 277-278.
121. Baldauf S. 2006. Africans are already facing climate change. The Christian Science Monitor, November 6. www.csmonitor.com/2006/1106/p04s01-woaf.html. Accessed April 23, 2008.
122. United Nations Environment Programme. 2007. Sudan: post-conflict environmental assessment, p. 8. http://postconflict.unep.ch/publications/UNEP_Sudan.pdf. Accessed April 23, 2008.
123. Ban K. 2007. A climate culprit in Darfur. The Washington Post, June 16.
124. United Nations. 2007. Ban Ki-moon calls on new generation to take better care of Planet Earth than his own. March 1. www.un.org/apps/news/story.asp?NewsID=21720&Cr=global&Cr1=warming. Accessed April 23, 2008.
125. Fleck F. 2004. Experts urge action to stop animal diseases infecting humans. British Medical Journal 328(7449):1158.
126. Greger M. 2007. The human/animal interface: emergence and resurgence of zoonotic infectious diseases. Critical Reviews in Microbiology 33(4):243-99.
127. Epstein PR and Mills E. 2005. Climate change futures: health, ecological and economic dimensions. The Center for Health and the Global Environment, Harvard Medical School. November. www.climatechangefutures.org/pdf/CCF_Report_Final_10.27.pdf. Accessed April 23, 2008.
128. World Health Organization. 2007. Outbreaks of Rift Valley fever in Kenya, Somalia and United Republic of Tanzania, December 2006-April 2007. Weekly Epidemiological Record 82(20):169-78.
129. Clarke J. 2007. Climate change pushes diseases north: expert. Reuters, March 9. www.reuters.com/article/healthNews/idUSL0920787420070309?sp=true. Accessed April23, 2008.
130. Viet Nam News. 2007. Veterinarians find themselves on front line in battle against bird flu. Viet Nam

News, July 23.
131. Them TT, Baudran E, Hoan ND, Loan LTT, Hao NV, and Dung NM. 2006. Poverty alleviation through livestock development in the Northern Upland of Vietnam. PALD Newsletter, September 2005-March 2006. www.avsf.org/library/cms_download.php?cat=article_document&doc_id=869. Accessed April 23, 2008.
132. Intergovernmental Panel on Climate Change. 2007. Fourth Assessment Report. Climate Change 2007: Synthesis Report. Summary for Policymakers, pp. 13-14.
133. The New York Times. 2007. Hot and cold. Editorial. The New York Times, April 8.
134. Connolly K. 2007. Pill stops cow burps and helps save the planet. The Guardian, March 23.
135. Personal correspondence with Winfried Drochner, professor of animal nutrition University of Hohenheim Stuttgart Germany March 28 2007.
136. Groom N. 2008. California cows start passing gas to the grid. Reuters, March 4. www.reuters.com/article/ELECTU/idUSN0440606220080304. Accessed March 23, 2008.
137. U.S. Environmental Protection Agency. 2007. EPA helps farmers turn livestock waste into wealth. January 18. http://yosemite.epa.gov/opa/admpress.nsf/756fc9115d0af011852572a00065593e/c9f1eb2189c4600d852572670065a77d!OpenDocument. Accessed April 23, 2008.
138. American Association of Insurance Services. 2007. Cow power: farms seeking to insure growing number of electricity-generating manure digesters. Viewpoint 31(3).
139. Sutherly B. 2007. Ohio farms planning to use cows, chickens to generate energy. Dayton Daily News, July 22. www.daytondailynews.com/n/content/oh/story/news/local/2007/07/21/ddn072207farmenergy.html. Accessed April 23, 2008.
140. U.S. Environmental Protection Agency. 2007. U.S. government accomplishments in support of the Methane to Markets partnership, p. 8. www.epa.gov/methanetomarkets/accompreport.htm. Accessed April 23, 2008.
141. Silverstein K. 2007. The appeal of animal waste. EnergyBiz Insider, August 10. www.energycentral.com/centers/energybiz/ebi_detail.cfm?id=367. Accessed April 23, 2008.
142. Environmental Power Corporation. 2005. About microgy. www.environmentalpower.com/companies/microgy/. Accessed April 23, 2008.
143. CNN. 2007. Cow methane: a trump card in the fight against global warming? CNN. www.cnn.com/2007/TECH/science/10/05/cow.methane/index.html. Accessed April 23, 2008.
144. PRNewswire-FirstCall. 2007. Smithfield Foods Joins the Chicago Climate Exchange. PRNewswire-FirstCall, February 25.
145. Crew J. 2007. Cargill commits to cut greenhouse emissions. MeatPoultry.com.
146. Pew Center on Global Climate Change. Greenhouse gas reporting and disclosure: key elements of a prospective U.S. program: projects and offsets. www.pewclimate.org/policy_center/policy_reports_and_analysis/brief_ghg_reporting_disclosure/ghg_projects.cfm. Accessed April 23, 2008.
147. The Climate Trust. A glossary of common carbon offset terms. www.climatetrust.org/pdfs/RFPs/Offset%20Glossary.pdf. Accessed April 23, 2008.
148. Business Week. 2007. Another inconvenient truth. Business Week, March 26. www.businessweek.com/magazine/content/07_13/b4027057.htm. Accessed April 23, 2008.
149. Harvey F and Fidler S. 2007. Industry caught in carbon 'smokescreen.'. Financial Times, April 25. www.ft.com/cms/s/0/48e334ce-f355-11db-9845-000b5df10621.html. Accessed April 23, 2008.
150. Seaboard Corporation. www.seaboardcorp.com. Accessed April 23, 2008.
151. The Associated Press. 2007. Biodiesel plant to be built in Guymon. Tulsa World, September 26. www.tulsaworld.com/news/article.aspx?articleID=070926_1__GUYMO33234. Accessed April 23, 2008.
152. Johnston T. 2007. Tyson teams with ConocoPhillips to produce renewable diesel fuel. MeatingPlace.com, April 16.
153. Lavigne P. 2007. Demand for fat plumps up pricing. The Des Moines Register, October 9.
154. Kaufman M. 2007. New allies on the Amazon: McDonald's, Greenpeace unite to prevent rainforest clearing. The Washington Post, April 24.

155. Agence France-Presse. 2007. Half-price Big Mac to fight global warming proves big hit in Japan. Agence France-Presse, September 4.
156. Hopkin M. 2007. Climate takes aim. Nature 446:706-7.
157. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, pp. 81-2.
158. Giles J. 2007. Climate change 2007: how to survive a warming world. Nature 446:716-7.
159. Food and Agriculture Organization of the United Nations. 2008. Domestic Animal Diversity Information System. Nguni cattle South Africa. http://lprdad.fao.org/cgi-bin/EfabisWeb.cgi?sid=9fd974b83b912176bc2b253fafa71519,reportsreport8a_50002437. Accessed April 23, 2008.
160. Food and Agriculture Organization of the United Nations. 2008. Domestic Animal Diversity Information System. Mukhatat chicken, Iraq. http://lprdad.fao.org/cgi-bin/EfabisWeb.cgi?sid=9fd974b83b912176bc2b253fafa71519,reportsreport8a_50005047. Accessed April 23, 2008.
161. For more information, see An HSUS report welfare issues with genetic engineering and cloning of farm animals at www.hsus.org/farm/resources/research/practices/genetic_engineering_and_cloning_farm_animals.html.
162. Boody G, Vondracek B, Andow D, et al. 2005. Multifunctional Agriculture in the United States. BioScience 55(1):27-38, citing: Rayburn E. 1993. Potential ecological and environmental effects of pasture and BGH technology. Chapter 6 In: Liebhardt W (ed.), The Dairy Debate, Consequences of Bovine Growth Hormone and Rotational Grazing Technologies (Davis, California: University of California Sustainable Agriculture Research and Education Program, pp. 247-76).
163. Bender M. 2001. Energy in agriculture and society: insights from the Sunshine Farm. March 28. www.landinstitute.org/vnews/display.v/ART/2001/03/28/3accb0712. Accessed April 23, 2008.
164. International Federation of Organic Agriculture Movements. 2004. The role of organic agriculture in mitigating climate change. www.ifoam.org/press/positions/pdfs/Role_of_OA_migitating_climate_change.pdf. Accessed April 23, 2008.
165. Mader P, Flieback A, Dubois D, Gunst L, Fried P, and Niggli U. 2002. Soil fertility and biodiversity in organic farming. Science 296(5573):1694-7.
166. Cederberg C and Stadig M. 2003. System expansion and allocation in life cycle assessment of milk and beef production. International Journal of Life Cycle Assessment 8(6):350-6.
167. Centre for Alternative Technology. 2007. Zero carbon Britain: an alternative energy strategy, p. 74. www.zerocarbonbritain.com/images/zerocarbonbritain.pdf. Accessed April 23, 2008.
168. Massachusetts v. EPA, 127 S. Ct. 1438. 2007. www.supremecourtus.gov/opinions/06pdf/05-1120.pdf. Accessed April 23, 2008.
169. Greenhouse L. 2007. Justices say EPA has power to act on harmful gases. The New York Times, April 3. www.nytimes.com/2007/04/03/washington/03scotus.html. Accessed April 23, 2008.
170. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. xxiii.
171. Merrett N. 2007. Climate concerns form over New Zealand dairy boom. Dairy Reporter, August 7. www.dairyreporter.com/news/ng.asp?n=78840&m=2DRE807&c=jcnfkplnnhjccxn. Accessed April 23, 2008.
172. Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, and de Haan C. 2006. Livestock's long shadow: environmental issues and options. Food and Agriculture Organization of the United Nations, p. xxiv.
173. Ricketts T, Daily G, Ehrlich P, and Michener C. 2004. Economic value of tropical forest to coffee. Proceedings of the National Academy of Sciences 101:12579-82.
174. Kyto Protocol. 2008. List of Annex 1 Parties to the Convention. United States of America. http://maindb.unfccc.int/public/country.pl?country=US. Accessed April 23, 2008.
175. Kyto Protocol. 2008. Status of Ratification. Modified April 18, 2008.

http://unfccc.int/files/kyoto_protocol/background/status_of_ratification/application/pdf/kp_ratification.pdf . Accessed April 23, 2008.
176. United Nations Framework Convention on Climate Change. A summary of the Kyoto Protocol. http://unfccc.int/kyoto_protocol/background/items/2879.php. Accessed April 23, 2008.
177. United Nations Framework Convention on Climate Change. Emissions trading. http://unfccc.int/kyoto_protocol/background/items/2880.php. Accessed April 23, 2008.
178. Prance GT. 2007. The economics of storing carbon. The American Prospect, September.
179. Global Canopy Programme. 2007. The Forests Now Declaration. www.forestsnow.org. Accessed April 23, 2008.
180. Global Canopy Programme. 2007. The Forests Now Declaration: about the declaration. www.forestsnow.org/resources/. Accessed April 23, 2008.
181. United Nations Framework Convention on Climate Change. The clean development mechanism. http://unfccc.int/kyoto_protocol/background/items/2881.php. Accessed April 23, 2008.
182. United Nations Framework Convention on Climate Change. Kyoto Protocol. http://unfccc.int/kyoto_protocol/items/2830.php. Accessed April 23, 2008.
183. United Nations Framework Convention on Climate Change. 2007. The United Nations Climate Change Conference in Bali. http://unfccc.int/meetings/cop_13/items/4049.php. Accessed April 23, 2008.
184. United Nations Framework Convention on Climate Change. 2007. Bali Action Plan. http://unfccc.int/files/meetings/cop_13/application/pdf/cp_bali_action.pdf. Accessed April 23, 2008.
185. United Nations Framework Convention on Climate Change. 2007. Reducing emissions from deforestation in developing countries: Approaches to stimulate action. Draft Decision-/CMP.3. Unedited final version. http://unfccc.int/files/meetings/cop_13/application/pdf/cp_redd.pdf. Accessed April 23, 2008.
186. Centre for Alternative Technology. 2007. Zero carbon Britain: an alternative energy strategy, p. 8. www.zerocarbonbritain.com/images/zerocarbonbritain.pdf. Accessed April 23, 2008.
187. Boody G, Vondracek B, Andow D, et al. 2005. Multifunctional Agriculture in the United States. BioScience 55(1):27-38.
188. Climate Counts. 2007. How you shop and invest changes the world. www.climatecounts.org/. Accessed April 23, 2008.
189. Climate Counts. 2007. Scorecard overview. www.climatecounts.org/scorecard.php. Accessed April 23, 2008.
190. Climate Counts. 2007. Scorecard overview: food products. www.climatecounts.org/scorecardlist.php?c=15. Accessed April 23, 2008.
191. Climate Counts. 2007. Scorecard overview: food services sector. www.climatecounts.org/scorecardlist.php?c=16. Accessed April 23, 2008.
192. Deutsch C. 2007. Climate change scorecard aims to influence consumers. The New York Times, June 19.
193. For more information, see Pirog R Van Pelt T Enshayan K and Cook E. 2001. Food fuel and freeways an Iowa perspective on how far food travels fuel usage and greenhouse gas emissions. A report for the Leopold Center for Sustainable Agriculture. www.leopold.iastate.edu/pubs/staff/ppp/food_mil.pdf. Accessed February 21 2008.
194. Stein A. 2007. Measuring your ecological footprint. Orion, May/June.
195. American Dietetic Association. 2007. Position of the American Dietetic Association: food and nutrition professionals can implement practices to conserve natural resources and support ecological sustainability. Journal of the American Dietetic Association 107:1033-43.
196. Baden-Meyer A. 2007. Reducing greenhouse gas pollution: why go vegetarian and locally organic. Organic Consumers Association, July. www.organicconsumers.org/articles/article_6044.cfm. Accessed April 23, 2008.
197. Natural Resources Defense Council. This green life. www.nrdcaction.org/subscribetgl.html. Accessed April 23, 2008.
198. Eisenberg S. 2007. Another reason to eat less meat. This Green Life, November. www.nrdc.org/thisgreenlife/0711.asp. Accessed April 23, 2008.
199. Environmental Defense. 2007. Fighting global warming with food: low-carbon choices for dinner. www.environmentaldefense.org/article.cfm?contentid=6604. Accessed April 23, 2008.
200. Greenpeace. The green living guide: go vegetarian. www.greenpeace.org/usa/getinvolved/green-

guide/green-lifestyle/go-vegetarian. Accessed April 23, 2008.
201. Walsh B. 2007. 51 things we can do to save the environment: 22. skip the steak. Time Magazine, April 9.
202. Agence France-Presse. 2008. Lifestyle changes can curb climate change: IPCC chief. Agence France-Presse, January 15. http://afp.google.com/article/ALeqM5iIVBkZpOUA9Hz3Xc2u-61mDlrw0Q. Accepted April 23, 2008.
203. Reijnders L and Soret S. 2003. Quantification of the environmental impact of different dietary protein choices. American Journal of Clinical Nutrition 78(Suppl):664-668S.
204. McMichael AJ, Powles JW, Butler CD, and Uauy R. 2007. Food, livestock production, energy, climate change, and health. The Lancet Energy and Health Series. The Lancet 370(9594):1253-63.