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Recommended Citation

Humane Society International, "An HSI Fact Sheet: The Impact of Animal Agriculture on the Environment and Climate Change in India: A Focus on Methane" (2010). *HSI FACT SHEETS*. 1.

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**HUMANE SOCIETY
INTERNATIONAL**

HSI Fact Sheet

The Impact of Animal Agriculture on the Environment and Climate Change in India: A Focus on Methane

Animal agriculture inefficiently consumes natural resources,¹ contributes to deforestation,² and produces immense quantities of animal waste, threatening water and air quality³ and contributing to climate change.⁴ The Food and Agriculture Organization (FAO) of the United Nations estimated in 2006 that animal agriculture was responsible for 18% of global, anthropogenic, or human-induced, greenhouse gas emissions⁵ and was “by far the single largest anthropogenic user of land.”⁶ Climate change poses significant challenges to India’s agricultural sector, which is already facing increased competition for land and water.⁷

Farm Animal Production and Intensification in India

According to the Food and Agriculture Organization (FAO) of the United Nations, approximately 67.5 billion land animals were raised globally for human consumption in 2008.⁸ India has the largest national herd of cattle and buffalo in the world, with over 170 million cattle and over 100 million buffalo.⁹ Over 38 million buffalo and 38 million cattle were used to produce milk in India in 2008.¹⁰ India is also one of the top five egg¹¹ and chicken meat¹² producers in the world. The nation’s 230 million egg-laying hens produce approximately 55.6 billion eggs per year.¹³

Global consumption of meat and milk has been growing since 1980, especially in developing countries. In India, between 1980 and 2005, per capita egg consumption more than doubled, while meat consumption grew 38% and milk consumption grew 69%.¹⁴

A growing number of farm animals are raised in industrial farm animal production (IFAP) facilities, where thousands or tens of thousands of animals are confined and concentrated, along with their waste, on the land.¹⁵ According to the FAO, industrial systems now produce approximately two-thirds of the world’s poultry meat and eggs, and more than half of all pork.¹⁶ In fact, “[i]n 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.”¹⁷ IFAP facilities (also called “factory farms”), compromise animal welfare,¹⁸ degrade the environment,¹⁹ and threaten public health,^{20,21,22,23} and rural livelihoods.²⁴

Nearly 80% of laying hen housing systems in India confine hens in cages.²⁵ Hens in battery cages spend their lives confined in tiny wire enclosures, where they are unable to engage in most of their natural behavior, such as nesting, perching, dustbathing, flying short distances, or even freely stretching their wings without touching other hens or the cage walls. Operations with 10,000 to 50,000 hens crowded together are common in India.²⁶ India also housed over 700 million broiler chickens in 2008.²⁷ A spokesperson for the Poultry Federation of India reportedly stated that India’s broiler chicken industry was comparable to that of developed countries,²⁸ which suggests that broiler chickens in India experience the crowded confinement,²⁹ and stressful handling³⁰ common in the U.S. chicken industry.

The dairy industry in India is also changing. The FAO predicts that, in India, “increase in demand for dairy products will put increasing pressure on dairy production systems; traditional breeds and feeding practices are likely to give way to higher-yielding breeds, associated intensification of production systems, increased disease risks, pollution and animal health issues, and a greater reliance on [feed] concentrates.”³¹

Unfortunately, industrialized animal agriculture is rapidly spreading globally, including in developing countries.^{32,33} The Pew Commission on Industrial Farm Animal Production warned that the known environmental and public health costs of IFAP “may be exacerbated by institutional weaknesses and governance problems common in developing countries.”³⁴

The Environmental Threat of Animal Agriculture

In 2006, the FAO published “Livestock’s Long Shadow: Environmental Issues and Options,” its landmark report assessing the impacts of animal agriculture. The FAO concluded that “[t]he livestock sector emerges as one of the top two or three most significant contributors to the most serious environmental problems, at every scale from local to global.”³⁵ It is concerning, then, that global meat and milk production are expected to approximately double between 2000 and 2050.³⁶

Waste

Traditional farming systems balance the number of animals with the crops’ ability to absorb the animals’ manure.³⁷ On factory farms, where thousands of animals are confined,³⁸ the amount of manure can overwhelm the ability of the surrounding land to absorb it.³⁹ When animal waste is over-applied to land and exceeds the capacity of soil and crops to assimilate its nutrients, it becomes a pollutant⁴⁰—and can contaminate water supplies and emit harmful gases into the atmosphere.⁴¹ According to the United States Department of Agriculture’s (USDA’s) Economic Research Service, in 1997, IFAP operations in the United States produced 1.12 million tonnes of spreadable nitrogen from manure; however, “cropland and permanent pasture controlled by operators of confined livestock and poultry operations is estimated to have assimilative capacity for only 38 percent of the calculated nitrogen available.”⁴² Similar studies need to be conducted in India to determine the quantities of manure being produced by IFAP operations relative to the surrounding land’s ability to assimilate nutrients from the waste.

According to the USDA, the problem of excess nutrients is most pronounced in poultry production operations, which produce 52% of the excess phosphorous and 64% of the excess nitrogen created by farm animal waste in the United States.⁴³ Run-off from poultry operations into the Chesapeake Bay in the eastern United States has been blamed for outbreaks of *Pfiesteria piscicida* in the water, killing fish and causing skin irritation, short-term memory loss, and other cognitive problems in those exposed.⁴⁴ An editorial in an October 2007 edition of a prominent local newspaper commented, “For too long, the poultry industry in this state has wielded economic and political clout to escape responsibility for its primary role in the slow, steady poisoning of the Chesapeake Bay.”⁴⁵

Resource Use

Approximately 70% of the world’s agricultural lands are dedicated to raising animals for food, including grazing and feed production.⁴⁶ Raising farm animals for human consumption consumes exorbitant amounts of cereals. Over 97% of global soymeal produced is fed farm animals, and during the last four decades of the 20th century, over 60% of the corn and barley crops were also fed to these animals.⁴⁷ Yet, the conversion of grains to meat is a highly inefficient process. It takes approximately 7 kilograms of grain to produce one kilogram of beef in developed countries. The ratios for pig meat (1 kg meat/4 kg grain) and poultry meat (1 kg meat/2 kg grain)⁴⁸ similarly exemplify this inefficiency.

This inefficient use of resources can be seen in India. Approximately ten percent of India's coarse grain production goes to feed farmed animals,⁴⁹ and approximately 50% of all corn consumed is used as animal feed—most of which is for poultry.⁵⁰ For 2010-2011, 76% of Indian oil meal is anticipated to go to animal feed.⁵¹ In addition to the inefficiency of converting grains to meat, using crops for poultry can negatively affect commodity prices. In 2008, it was reported that a shift to using rice for animal feed raised rice prices in the South,⁵² where rice is a basic staple in people's diets.⁵³

Greenhouse Gas Emissions (GHGs) and Climate Change

According to a 2006 estimate by the FAO, globally, animal agriculture is responsible for 18% of anthropogenic GHGs.⁵⁴ Therefore, this sector offers a key opportunity for the immediate mitigation of anthropogenic climate impacts worldwide,⁵⁵ including in India,⁵⁶ which is the fifth largest GHG emitter in the world.⁵⁷

Almost every part of the animal production chain pollutes the air or contributes to climate change.⁵⁸ The sector emits significant amounts of three of the most important GHGs: carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O).⁵⁹ In fact, globally the farm animal sector accounts for:

- 9% of human-induced CO₂ emissions⁶⁰
- 35–40% of human-induced CH₄ emissions,⁶¹ which has 25 times the global warming potential (GWP), or power,⁶² of CO₂ over 100 years,⁶³ and
- 65% of human-induced N₂O emissions,⁶⁴ which has about 300 times the GWP of CO₂.⁶⁵

CO₂: Carbon dioxide emissions from this sector are produced through nitrogen fertilizer production for feed, on-farm fossil fuel use, deforestation to make way for grazing and animal feed production, and pasture desertification,⁶⁶ which can result from overgrazing by farm animals.⁶⁷ An estimated 41 million tonnes of CO₂ are emitted from fertilizer production for feed crops each year.⁶⁸ Given the amounts of coarse grains and corn that are used to feed farm animals in India,^{69,70} it is likely that significant CO₂ emissions result from raising animals for food.

CH₄: Enteric fermentation and manure management are the key causes of animal agriculture's methane emissions.⁷¹ Enteric fermentation is a microbial fermentation that takes place in the digestive systems of ruminant animals, such as cattle, sheep, and buffalo.⁷² Enteric fermentation is responsible for 49% of India's methane emissions, 63% of its agricultural emissions, and 12% of total emissions.⁷³ Buffalo account for nearly two-thirds of methane emissions from enteric fermentation, and are the most significant methane source in India.⁷⁴ Per-head methane emissions (arising from enteric fermentation) from crossbred dairy cows are greater than emissions from indigenous cattle, and buffalo have the largest emission coefficients relative to all dairy cattle.⁷⁵ The population of crossbred, dairy-producing cattle in India increased between 2000 and 2005,⁷⁶ as there is a growing preference for high yield animals.⁷⁷ There was also a 9% increase in the buffalo population from 1997-2003.⁷⁸

Manure is responsible for the remaining portion of global methane emissions from farm animals⁷⁹ and accounts for approximately 5% of animal agriculture's GHG emissions.⁸⁰

N₂O: The farm animal sector also is responsible for the majority of the world's human-induced nitrous oxide emissions.⁸¹ Nitrous oxide emissions from animal agriculture originate primarily from manure, but also from fertilizer for feed crops,⁸² and contribute approximately 31% of animal agriculture's GHG emissions.⁸³

Conclusion

Mitigating the animal agriculture sector's significant yet underappreciated role in climate change and environmental problems is vital for the health and sustainability of the planet, and its human and nonhuman

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inhabitants. As “the single largest anthropogenic user of land”⁸⁴ and responsible for an estimated 18% of human-induced GHG emissions,⁸⁵ the farm animal production sector must be held accountable for its many deleterious impacts, and society must achieve changes in animal agricultural practices worldwide.

Methane’s relatively short atmospheric lifetime compared to carbon dioxide (≈ 10 years^{86,87,88} vs. $\approx 100+$ years⁸⁹) means that reducing methane emissions would have a more immediate and significant impact on mitigating climate change than just reducing CO₂ emissions.⁹⁰ Thus, tremendous opportunity to effectively mitigate climate change in the near term lies in the dairy sector,⁹¹ particularly in India which has the largest combined population of cattle and buffalo in the world⁹² with nearly 40 million milk-producing buffalo and cattle, each.⁹³ GHG emissions from animal agriculture are fundamentally related to the size of farm animal populations.⁹⁴ Therefore, aggressive breeding programs to increase dairy animal populations in India are not advisable; breeding programs must be designed with the goal of reducing cattle and buffalo populations. This should not be done by increasing dairy animal productivity in ways that are negative for animal welfare.

Individually, incorporating environmentally sound and animal welfare-friendly practices into daily life, including a reduction in meat, milk, and egg consumption, can reduce our environmental impact. The production, processing, transport, and preparation of an Indian, non-vegetarian meal including mutton collectively emits nearly twice the GHGs as that of a vegetarian meal that excludes dairy products and eggs.⁹⁵

¹Nellemann C, MacDevette M, Manders T, et al. (eds.). 2009. The Environmental Food Crisis: the environment's role in averting future food crises (Norway: United Nations Environment Programme, p. 26). http://www.grida.no/res/site/file/publications/FoodCrisis_lores.pdf. Accessed May 18, 2010.

²Steinfeld 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.

³Pew Commission on Industrial Farm Animal Production. 2008. Putting meat on the table: industrial farm animal production in America, p. 23, 25, 27. <http://www.ncifap.org/bin/e/j/PCIFAPFin.pdf>. Accessed May 18, 2010.

⁴Steinfeld 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, 113 Table 3.12.

⁵Steinfeld 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. 112.

⁶Steinfeld 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.

⁷Indian Network for Climate Change Assessment, Ministry of Environment & Forests, Government of India. 2010. Climate change and India: a 4x4 assessment: a sectoral and regional analysis for 2030s, p. 67-88.

⁸Food and Agriculture Organization of the United Nations. FAO Statistical Database, FAOSTAT. <http://faostat.fao.org/site/567/default.aspx>. Accessed May 13, 2010.

⁹Food and Agriculture Organization of the United Nations. FAO Statistical Database, FAOSTAT. <http://faostat.fao.org/site/567/default.aspx>. Accessed May 13, 2011.

¹⁰Food and Agriculture Organization of the United Nations. FAO Statistical Database, FAOSTAT. <http://faostat.fao.org/site/567/default.aspx>. Accessed April 22, 2011.

¹¹Food and Agriculture Organization of the United Nations. FAO Statistical Database, FAOSTAT. <http://faostat.fao.org/site/567/default.aspx>. Accessed May 13, 2011.

¹²Department of Animal Husbandry, Dairying and Fisheries. 2007-8. Annual Report, p.25.

¹³Food and Agriculture Organization of the United Nations. FAO Statistical Database, FAOSTAT. <http://faostat.fao.org/site/567/default.aspx>. Accessed May 2, 2011.

¹⁴Food and Agriculture Organization of the United Nations. 2009. The state of food and agriculture: livestock in the balance. (Rome, Italy: Food and Agriculture Organization of the United Nations, p. 11 Table 1).

-
- ¹⁵ Pew Commission on Industrial Farm Animal Production. 2008. Putting meat on the table: industrial farm animal production in America, pp. 6, 13, 23, 33, 42. <http://www.ncifap.org/bin/e/j/PCIFAPFin.pdf>. Accessed May 18, 2010.
- ¹⁶ Food and Agriculture Organization of the United Nations. 2009. The state of food and agriculture: livestock in the balance (Rome, Italy: FAO, p. 27). <http://www.fao.org/docrep/012/i0680e/i0680e.pdf>. Accessed May 19, 2010.
- ¹⁷ Vergé XPC, De Kimpe C, and Desjardins RL. 2007. Agricultural production, greenhouse gas emissions, and mitigation potential. *Agricultural and Forest Meteorology* 142:255-269.
- ¹⁸ Pew Commission on Industrial Farm Animal Production. 2008. Putting meat on the table: industrial farm animal production in America, p. 33. <http://www.ncifap.org/bin/e/j/PCIFAPFin.pdf>. Accessed May 18, 2010.
- ¹⁹ Pew Commission on Industrial Farm Animal Production. 2008. Putting meat on the table: industrial farm animal production in America, pp. 23, 25. <http://www.ncifap.org/bin/e/j/PCIFAPFin.pdf>. Accessed May 18, 2010.
- ²⁰ Pew Commission on Industrial Farm Animal Production. 2008. Putting meat on the table: industrial farm animal production in America, p.17. www.ncifap.org/_images/PCIFAP_FINAL_REPORT.pdf. Accessed July 22, 2009.
- ²¹ Donham KJ, Wing S, Osterberg D, et al. 2007. Community health and socioeconomic issues surrounding concentrated animal feeding operations. *Environmental Health Perspectives*. 115(2):317-20.
- ²² Greger M. 2006. *Bird Flu: A Virus of Our Own Hatching* (New York, NY: Lantern Books). p. 347.
- ²³ Barrett JR. 2005. Airborne bacteria in CAFOs: transfer of resistance from animals to humans. *Environmental Health Perspective*. 113(2):A116-7.
- ²⁴ Spellman FR and Whiting NE. 2007. *Environmental Management of Concentrated Animal Feeding Operations (CAFOs)* (Boca Raton, FL: Taylor & Francis Group, pp. 6-7).
- ²⁵ Van der Sluis W. 2008. Global Egg Production is Increasing. *World Poultry* 24(1):20-1.
- ²⁶ Rattanani J. 2006. India to see tremendous changes. *World Poultry Review* 22:6.
- ²⁷ Food and Agriculture Organization of the United Nations. FAO Statistical Database, FAOSTAT. <http://faostat.fao.org/site/567/default.aspx>. Accessed March 14, 2011 .
- ²⁸ Clements M. 2010. An overview of the Indian Poultry Industry. Poultry International. http://www.wattagnet.com/An_overview_of_the_Indian_poultry_industry.html. Accessed May 2, 2011.
- ²⁹ Estevez I. 2007. Density allowances for broilers: where to set the limits? *Poultry*
- ³⁰ Lacy MP and Czarick M. 1998. Mechanical harvesting of broilers. *Poultry Science* 77:1794-7.
- ³¹ Sharma VP, Delgado CL, Staal S, and Singh RV. 2003. Annex III: Livestock industrialization project: phase II -policy, technical, and environmental determinants and implications of the scaling-up of milk production in India. United Nations Food and Agriculture Organization and International Food Policy Research Insitutue, Project on livestock industrialization, trade and social-health-environment impacts in developing countries.
- ³² Food and Agriculture Organization of the United Nations. 2009. The state of food and agriculture: livestock in the balance (Rome, Italy: FAO, p. 27). <http://www.fao.org/docrep/012/i0680e/i0680e.pdf>. Accessed May 19, 2010.
- ³³ Vergé XPC, De Kimpe C, and Desjardins RL. 2007. Agricultural production, greenhouse gas emissions, and mitigation potential. *Agricultural and Forest Meteorology* 142:255-269.
- ³⁴ Pew Commission on Industrial Farm Animal Production. 2008. Putting meat on the table: industrial farm animal production in America, p. 7. www.ncifap.org/_images/PCIFAP_FINAL_REPORT.pdf. Accessed July 22, 2009.
- ³⁵ 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. xx.
- 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, p. xx.
- ³⁷ Pew Commission on Industrial Farm Animal Production. 2008. Putting meat on the table: industrial farm animal production in America, p. 23. www.ncifap.org/_images/PCIFAP_FINAL_REPORT.pdf. Accessed July 22, 2009.

-
- ³⁸ Pew Commission on Industrial Farm Animal Production. 2008. Putting meat on the table: industrial farm animal production in America, p. 13, 42. www.ncifap.org/_images/PCIFAP_FINAL_REPORT.pdf. Accessed July 22, 2009.
- ³⁹ Pew Commission on Industrial Farm Animal Production. 2008. Putting meat on the table: industrial farm animal production in America, p. 23. www.ncifap.org/_images/PCIFAP_FINAL_REPORT.pdf. Accessed July 22, 2009.
- ⁴⁰ Pew Commission on Industrial Farm Animal Production. 2008. Putting meat on the table: industrial farm animal production in America, p. 23. www.ncifap.org/_images/PCIFAP_FINAL_REPORT.pdf. Accessed July 22, 2009.
- ⁴¹ U.S. Department of Agriculture Economic Research Service. 2008. Environmental interactions with agricultural production: animal agriculture and the environment. <http://www.ers.usda.gov/Briefing/AgAndEnvironment/animalagriculture.htm>. May 2, 2011.
- ⁴² Gollehon N and Caswell M. 2000. Confined animal production poses manure management problems. U.S. Department of Agriculture Economic Research Service. Agricultural Outlook, September, pp. 12-18. www.ers.usda.gov/publications/agoutlook/sep2000/ao274f.pdf. Accessed July 22, 2009.
- ⁴³ Gollehon N, Caswell M, Ribaldo M, Kellogg R, Lander C, and Letson D. 2001. Confined animal production and manure nutrients. U.S. Department of Agriculture Economic Research Service. Agriculture Information Bulletin No. 771, p. 20. www.ers.usda.gov/publications/aib771/aib771.pdf. Accessed June 17, 2008.
- ⁴⁴ Morris, Glen. 1999. Pflisteria, 'the cell from hell' and other toxic algal nightmares. Clinical Infectious Diseases (28).
- ⁴⁵ Editorial. 2007. No more free pass. The Baltimore Sun, October 18, p. A20.
- ⁴⁶ 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.
- ⁴⁷ 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. 38 -39, 43.
- ⁴⁸ Rosegrant MW, Leach N, and Gerpacio RV. 1999. 'Meat or wheat for the next millennium?' Plenary lecture: alternative futures for world cereal and meat consumption. Proceedings of the Nutrition Society 58:219-234.
- ⁴⁹ Dhankhar D. 2009. India: livestock products annual. United States Department of Agriculture, Foreign Agricultural Service, Global Agricultural Information Network Report, No. IN9119, September 14.
- ⁵⁰ Singh S. 2011. India: grain feed annual. United States Department of Agriculture, Foreign Agricultural Service, Global Agricultural Information Network Report, No. IN1117, February 23.
- ⁵¹ Aradhay A. 2010. India: oil seeds and products annual. United States Department of Agriculture, Foreign Agricultural Service, Global Agricultural Information Network Report, No. IN1031, April 16.
- ⁵² Jayaramiah J. 2008. Rice price up as poultry farms replace feed. The Financial Express, May 28. <http://www.financialexpress.com/news/rice-price-up-as-poultry-farms-replace-feed/315491/0>. Accessed April 27, 2011.
- ⁵³ Moretti D, Zimmermann MB, Muthayya S, Thankachan P, Lee T, Kurpad AV, and Hurrell RF. 2006. Extruded rice fortified with micronized ground ferric pyrophosphate reduces iron deficiency in Indian schoolchildren: a double-blind randomized controlled trial. American Journal of Clinical Nutrition 84(4) 822-829, p. 822-823.
- ⁵⁴ 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. 112.
- ⁵⁵ Unger N, Bond TC, Wang JS, et al. 2010. Attribution of climate forcing to economic sectors. Proceedings of the National Academy of Sciences of the United States of America 107(8):3382 -3387.
- ⁵⁶ Government of India, Ministry of Environment and Forests. 2010. India: greenhouse gas emissions 2007, p. v. http://moef.nic.in/downloads/public-information/Report_INCCA.pdf. Accessed April 27, 2011.
- ⁵⁷ Government of India, Ministry of Environment and Forests. 2010. India: greenhouse gas emissions 2007, forward. http://moef.nic.in/downloads/public-information/Report_INCCA.pdf. Accessed April 27, 2011.
- ⁵⁸ 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. 79.
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-
- ⁵⁹Steinfeld 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.
- ⁶⁰Steinfeld 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. 112.
- ⁶¹Steinfeld 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. 112.
- ⁶² U.S. Environmental Protection Agency. 2011. Inventory of U.S. greenhouse gas emissions and sinks: 1990-2009, p. ES-2. http://www.epa.gov/climatechange/emissions/downloads/11/US-GHG-Inventory-2011-Complete_Report.pdf. Accessed May 15, 2011.
- ⁶³Forster P, Ramaswamy V, Artaxo P, et al. 2007. Changes in atmospheric constituents and in radiative forcing. In: Solomon S, Qin D, Manning M, et al (eds.), *Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, p. 212 Table 2.14).
- ⁶⁴Steinfeld 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.
- ⁶⁵Forster P, Ramaswamy V, Artaxo P, et al. 2007. Changes in atmospheric constituents and in radiative forcing. In: Solomon S, Qin D, Manning M, et al (eds.), *Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, p. 212 Table 2.14).
- ⁶⁶Steinfeld 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. 86-91,93, 113 Table 3.12.
- ⁶⁷Steinfeld 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. 30, 66.
- ⁶⁸Steinfeld 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. 86-88.
- ⁶⁹ Dhankhar D. 2009. India: livestock products annual. United States Department of Agriculture, Foreign Agricultural Service, Global Agricultural Information Network Report, No. IN9119, September 14.
- ⁷⁰ Singh S. 2011. India: grain feed annual. United States Department of Agriculture, Foreign Agricultural Service, Global Agricultural Information Network Report, No. IN1117, February 23.
- ⁷¹Steinfeld 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. 113 Table 3.12.
- ⁷²Steinfeld 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. 95 -96.
- ⁷³ Government of India, Ministry of Environment and Forests. 2010. India: greenhouse gas emissions 2007, p. viii-ix. http://moef.nic.in/downloads/public-information/Report_INCCA.pdf. Accessed April 27, 2011.
- ⁷⁴ Government of India, Ministry of Environment and Forests. 2010. India: greenhouse gas emissions 2007, p. 24. http://moef.nic.in/downloads/public-information/Report_INCCA.pdf. Accessed April 27, 2011.
- ⁷⁵ Garg A, Shukla PR, Kapshe M, and Menon D. 2004. Indian methane and nitrous oxide emissions and mitigation flexibility. *Atmospheric Environment* 38:1968-77.
- ⁷⁶ Government of India, Ministry of Agriculture, Department of Animal Husbandry, Dairying and Fisheries. 2006. Basic Animal Husbandry Statistics, p. 9 (table 4) and p. 15 (table 10). New Delhi, DAHDF.
- ⁷⁷ Government of India, Ministry of Agriculture, Department of Animal Husbandry, Dairying and Fisheries. 2006. Basic Animal Husbandry Statistics, p. 2. New Delhi, DAHDF.
- ⁷⁸ Government of India, Ministry of Agriculture, Department of Animal Husbandry, Dairying and Fisheries. 2006. Basic Animal Husbandry Statistics, p. 2. New Delhi, DAHDF.
- ⁷⁹Steinfeld 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. 113 Table 3.12.
- ⁸⁰Steinfeld 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. 113 Table 3.12.

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- ⁸¹Steinfeld 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. 114.
- ⁸²Steinfeld 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. 104-105, 113 Table 3.12.
- ⁸³Steinfeld 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. 113 Table 3.12.
- ⁸⁴Steinfeld 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.
- ⁸⁵Steinfeld 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. 112.
- ⁸⁶Boucher O, Friedlingstein P, Collins B, and Shine KP. 2009. The indirect global warming potential and global temperature change potential due to methane oxidation. *Environmental Research Letters* 4:1–5.
- ⁸⁷Unger N, Bond TC, Wang JS, et al.. 2010. Attribution of climate forcing to economic sectors. *PNAS* 107(8):3382–87.
- ⁸⁸Forster P, Ramaswamy V, Artaxo P, et al. 2007. Changes in atmospheric constituents and in radiative forcing. In: Solomon S, Qin D, Manning M, et al (eds.), *Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, p. 212 Table 2.14).
- ⁸⁹Moore FC, and MacCracken MC. 2009. Lifetime-leveraging: An approach to achieving international agreement and effective climate protection using mitigation of short-lived greenhouse gases. *International Journal of Climate Change Strategies and management* 1(1):42–62.
- ⁹⁰Moore FC, and MacCracken MC. 2009. Lifetime-leveraging: An approach to achieving international agreement and effective climate protection using mitigation of short-lived greenhouse gases. *International Journal of Climate Change Strategies and management* 1(1):42–62.
- ⁹¹Food and Agriculture Organization of the United Nations, Animal Production and Health Division. 2010. *Greenhouse Gas Emissions From the Dairy Sector: A Life Cycle Assessment*, pp. 10-11.
- ⁹²Food and Agriculture Organization of the United Nations. FAO Statistical Database, FAOSTAT. <http://faostat.fao.org/site/567/default.aspx>. Accessed May 13, 2011.
- ⁹³Food and Agriculture Organization of the United Nations. FAO Statistical Database, FAOSTAT. <http://faostat.fao.org/site/567/default.aspx>. Accessed April 22, 2011.
- ⁹⁴U.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.
- ⁹⁵Pathak H, Jain N, Bhatia A, Patel J, and Aggarwal PK. 2010. Carbon footprints of Indian food items. *Agriculture, Ecosystems and Environment* doi:10.1016/j.agee.2010.07.002.

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Last updated in May 2011.