The Environmental Safety and Benefits of Pharmaceutical Technologies in Beef Production

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October 2007

Executive Summary

Growth promoting hormones are a key component of North American beef production. Their use over the past 50-plus years has proven beneficial not only to beef producers, but to consumers and the environment, all of which benefit from lower costs and more efficient use of scarce natural resources. In short, they allow us to achieve the old Yankee maxim of producing more from less.

Every food safety authority who has examined the use of pharmaceutical technologies and the resulting beef products has found them to be both safe and wholesome, helping to produce an overall leaner beef supply with minimal residues with no practical health consequence. These facts are reinforced not only by the Food and Drug Administration (FDA) of the United States and Health Canada, but also by the Codex Alimentarius Committee of the Food and Agriculture Organization (FAO)/World Trade Organization (WHO), the United Nations and even a conference established by the European Agriculture Commission.

There are six hormones approved for use in beef production in more than 30 countries. Three of these are naturally occurring hormones and the other three are synthetically produced. The three natural hormones (testosterone, estradiol and progesterone) have been deemed completely safe for use in beef production, are a natural part of all mammalian physiology and are released into the environment at levels well within natural ranges. Their use is uncontroversial.

The three synthetic growth enhancing hormones are melengestrol acetate (MGA), trenbolone acetate (TBA) and zeranol. Basically, these are more stable analogs of the three natural hormones. All three of these synthetic hormones enter the environment predominantly in the same way as the natural: via cattle waste. All three have undergone extensive eco-safety assessments, including worst-case estimates of their levels in cattle wastes, runoff from cattle feedlots and runoff from land on which the wastes have been applied. In addition, there is a growing body of science regarding their fate in real-world environments.

But beyond this reassuring history, there are clearly enormous environmental benefits to be gained from use of these products. Increased feed use efficiency, reduced land

requirements, and reduced greenhouse gas emissions per pound of beef produced have all been conclusively demonstrated.

Comparing conventional beef production to an alternative grass-only beef production system using an economic/production model created by Iowa State University shows that growth promoting hormones and ionophores decrease the land required to produce a pound of beef by two-thirds, with one-fifth of this gain resulting from growth enhancing pharmaceuticals. For example, more than 5 acre-days are needed to produce just one pound of beef from cattle raised on grass only in an organic system compared to the less than 1.7 acre days needed in a conventional grain-fed feedlot system using pharmaceutical technology. One-fifth of the saved land from grain feeding and pharmaceuticals is a result of growth promotants.

Grain feeding combined with growth promotants also results in a nearly 40 percent reduction in greenhouse gases (GHGs) per pound of beef compared to grass feeding (excluding nitrous oxides), with growth promotants accounting for 25 percent of the emissions reductions.

In short, growth promoting implants safely and responsibly allow farmers and ranchers to produce more beef from less grain, using less land, and creating less waste and fewer greenhouse gas emissions.

Miniscule units of measure referenced in this paper

Extremely sensitive and sophisticated new measurement devices enable scientists to identify even the most miniscule amounts of growth promoting pharmaceuticals (and other compounds) in the target animal and in the environment, giving consumers even greater assurance of the safety of these technologies in beef production. For example, a µ (microgram) is a millionth of a gram, a *ng* (nanogram) is a billionth of a gram, roughly equivalent to a kernel of wheat in a train carload of wheat, and ppt (part per trillion) which is equivalent to 1 second in 32,000 years!

Human Safety of Growth Enhancing Pharmaceuticals

The first and foremost question about growth promoting hormones, of course, is whether their use is safe for consumers. In one word, Yes.

Three of the six hormones approved by the FDA for growth enhancement in beef production are naturally occurring. Testosterone, estradiol and progesterone are produced in significant quantities throughout the lifetime of every man, woman and child, and are required for the bodies of all mammals to function and mature. They are manufactured for use in beef production by transforming natural hormone precursors obtained from soybeans, agave and other plants.

The first safety factor is the way they are given to cattle. Except for MGA (administered via feed), FDA regulations only allow growth promoting hormones to be administered through time-release implants placed under the skin of the animal's ear at about six months of age. Each implant contains a specific, legally authorized dose of hormones. The implant ensures that the hormone is released into the animals' bloodstream very slowly so that the concentration of the hormone in the animal remains relatively constant and low. Because the ear is discarded at harvest, the implant does not enter the food chain.

Second, the doses are low. The science indicates that use of supplemental hormones in cattle has only a miniscule effect on hormone levels in beef – at amounts much lower than the natural hormone levels in beef or the amounts produced naturally in our own bodies. According to the U.S. Department of Agriculture, USDA, a person would need to eat more than 13 pounds of beef from an implanted steer to equal the amount of estradiol naturally found in a single egg![1] One glass of milk contains about nine times as much estradiol as 0.5 pound of beef from an implanted steer. And remember, it's not just animal products that contain hormonally active chemicals. A half-pound potato has 245 nanograms (ng, or 1 billionth of a gram) of estrogen equivalent, compared with 1.3 ng for a quarter-pound of untreated beef and 1.9 ng for beef from an implanted steer.[2]

And, don't forget that our own bodies produce these same hormones every day in amounts a hundred times or more higher than the amounts found in beef. One pound of beef from an animal implanted with estradiol contains approximately 15,000 times less of this hormone than the amount produced daily by the average man and about 9 million times less than the amount of estrogen produced by a pregnant woman.

The whole world's health experts say beef hormones are safe, not just those in the United States and Canada. The WHO/FAO Expert Committee extensively modeled theoretical consumer exposures to growth promoting beef hormone residues based on worst-case exposure estimates. They found, as did the FDA and USDA, no indication of appreciable risk. TheWHO/FAO committee calculated that, even assuming the highest residue levels found in beef, a person consuming one pound (~500 g) of beef from an implanted steer would ingest only 50 ng of additional estradiol compared to non-implanted beef.[3] That's less than one-thirtieth of the

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[1] Foreign Agricultural Service, USDA 1999. A Primer on Beef Hormones. Available at: http://stockholm.usembassy.gov/Agriculture/hormone.html

[2] Ibid.

[3] Joint FAO/WHO Expert Committee on Food Additives. 1999. Summary and Conclusions of the Fifty-second Meeting.

acceptable daily intake (ADI) of estradiol for a 75-pound child established by the Expert Committee. (See “ADI Explained”)

More than 30 other countries currently allow use of these hormones in beef production, and even European scientific groups have deemed hormones safe for use. Here is just a partial list of the high-powered expert groups that have declared the use of supplemental hormones in beef production safe:
- **U.S. Food and Drug Administration,** which has approved nearly a dozen different formulations since the late 1980s
- **European Economic Community Scientific Working Group on Anabolic Agents,** chaired by Dr. G. E. Lamming in 1987
- **International Codex Alimentarius Committee on Residues of Veterinary Drugs in Foods,** in 1987; the Codex sets safety standards for international trade under the WTO
- **European Agriculture Commission Scientific Conference on Growth Promotion in Meat Production,** in 1995
- **FAO/WHO Joint Expert Committee on Food Additives (JECFA),** 1981, 1983, 1988, 1999
- **Sub-Group of the Veterinary Products Committee of the British Ministry of Agriculture, Fisheries, and Food,** 1999

Acceptable Daily Intake (ADI) Explained

An ADI is the dose of a substance experts believe is totally safe to consume each day for a lifetime. ADIs are established by taking a safe, no-effect dose in the most sensitive animal tested and then applying a suitable “uncertainty factor” to ensure against any health impacts, ranging from 100- to 1,000-fold less than the no-effect dose. ADIs are listed as a dose-per-pound or kilogram of a person’s body weight.

For example, the ADI for estradiol is 50 ng per kilogram of body weight, based on a no-effect dose in women of 300 micrograms (μg, millionths of a gram) per 60 kg/person/day and an uncertainty factor of 100. (Here’s the math: 300 μg ÷ 60 kg = 5 μg/kg. 5 μg ÷ 100 uncertainty factor = 0.05 μg/kg, or 50 ng/kg.)

Table 1 lists the beef hormone ADIs, the corresponding dose for a 75-pound child and 150 pound adult, and the percentage of the ADI for a 150-pound adult in an average pound of beef from an implanted/treated animal (based on values reported by USDA and in the 1999 WHO/FAO Expert Committee report). As can clearly be seen, no residues exceed more than 5.25 percent of the ADI.

Table 1. Acceptable Daily Intake versus maximal exposure estimates of USDA and WHO/FAO Expert Committee.

Growth Promoting Hormone	WHO/FAO Acceptable Daily Intake (per kg body weight)	ADI for 75 lb person	ADI for 150 lb person	Maximum theoretical percent of ADI (150-lb person) in a pound of implanted beef
Estradiol	0.05 μg	1.75 μg	3.5 μg	(50 ng/lb) **1.50%**
Progesterone	30 μg	1,050 μg	2,100 μg	(100 μg/lb) **5.25%**
Testosterone	2 μg	70 μg	140 μg	(46 ng/lb) **0.03%**
MGA	0.03 μg	1.05 μg	2.1 μg	(50 ng/lb) **2.30%**
TBA	0.02 μg	0.7 μg	1.4 μg	(8 ng/lb) **0.57%**
Zeranol	0.5 μg	17.5 μg	35 μg	(0.09 μg/lb) **0.25%**

Eco-safety of Growth Enhancing Pharmaceuticals

The environmental safety of growth enhancing supplemental hormones is examined and established as an integral part of the FDA's approval process. The FDA's Center for Veterinary Medicine must issue a "Finding of No Significant Impact" ruling before a veterinary product such as a growth enhancing hormone supplement can be used.

This process reviews all aspects of the compound and its use in assessing possible environmental effects, including expected environmental concentrations, exposure estimates based on chemical properties and fate data, and eco-impact assessments based on indicator organism toxicity testing.

The physiology, pharmacology and toxicology of the three FDA-approved natural hormones used in beef production has been extensively studied and well-established over the past 60 years. For example, the hormone estradiol is produced in the follicle of the ovaries of all mammals and is excreted from cows primarily (84 percent) as the non-estrogenic metabolite 17-alpha estradiol.

FDA has determined that the use of these natural hormones for growth enhancement in beef poses no risk to the environment because the amounts administered to weaned calves, steers and heifers via slow-release implants are much lower than the amounts of these hormones naturally produced in mature bulls and pregnant cows. Thus, the products are a natural part of the environment, will be released into the environment in amounts well within natural levels, and will degrade naturally and rapidly.

The three synthetic growth enhancing hormones are melengestrol acetate (MGA), trenbolone acetate (TBA) and zeranol. MGA and TBA are made using standard pharmaceutical manufacturing techniques, whereas zeranol is derived from the natural product of a common fungus. The environmental assessments of these synthetic growth hormones were extensive, including all aspects of their production, use and environmental fate.
All three enter the environment primarily through the use of cattle waste as fertilizer. Cattle receiving growth promoting hormones are either pastured (after weaning but before finishing), where the wastes are deposited on pasture/grasslands, or they are finished in feedlots, where the wastes are collected, stored and eventually applied to cropland as fertilizer.

To assess the environmental risk, data collected by independent third-party research companies on a multitude of aspects of the compounds are submitted to the FDA to demonstrate the lack of environmental risk. These include:

- Propensity of the chemical to bioaccumulate in animals
- Concentrations of product and/or metabolites in cattle waste
- Degradation rate of product/metabolites during cattle waste storage
- Degradation rate of product/metabolites when applied to crop fields
- Degradation rate of product/metabolites when exposed to sunlight
- Mineralization rate of product/metabolites in manure or soil
- Tendency for the product/metabolite to attach to soil particles (sorbtion)
- Toxicity of product/metabolites to terrestrial organisms (soil microorganisms, earthworms)
- Likelihood that product/metabolites will be transported in field run-off, including solubility in various types of soils
- Potential toxicity to aquatic organisms

In all cases, after examining the data for metabolism, excretion, degradation and runoff potential, FDA determined that the use of these three growth enhancing products will not significantly impact the environment, including aquatic organisms.

In practice, this regulatory science review process is lengthy and requires considerable research. Here is a brief summary of key aspects of the environmental assessments for the three synthetic growth enhancing hormones, as well as a comparison of expected exposures to relevant eco-toxicology data.

Eco-safety Assessment of Melegestrol Acetate (MGA)

MGA is given to heifers by being mixed into or top-dressed onto their feed. As such, it is used almost entirely in feedlot situations rather than pastures, so the wastes are collected and applied to crop fields as fertilizer as per existing regulations regarding the protection of surface waters.

In examining the environmental risk, FDA considered a worst-case environmental exposure scenario.[4] Heifers are fed a maximum dose of 0.5 mg MGA/heifer/day, so it was assumed that the animals received this dose every day during a 120-day stay at a feedyard. This results in a total dose of 60 mg. All 60 mg of MGA were assumed to be excreted undegraded (rather than being metabolized into less bioactive metabolites) leading to a 120-day accumulation of 817 kilograms of dried manure, with a manure MGA concentration of 73 parts per billion (ppb) (see Figure 1).

It was then assumed that the manure was applied to cropland at the higher than normal rate of 20 tons of manure per acre. After incorporating this manure into the top 6 inches of soil, the soil would contain 1.8 ppb of MGA (note: one part per billion is analogous to 1 second in 32 years or 1 inch in 16,000 miles).

It is important to note that this “worst-case” estimate is significantly higher than would be expected under real-world conditions. For one thing, most cattle at feedlots are not heifers, but are steers – and steers are not given MGA. Therefore, even assuming conservatively that heifers make up fully one-third of the cattle population at a feedlot, the MGA concentration would still be diluted by two-thirds down to 0.6 ppb.

Most importantly, the research shows that MGA binds strongly to soil particles. So, even if the soil concentration of MGA reached the improbable 1.8 ppb, research demonstrates that the water in the soil would contain less than 0.01 ppb. At a more realistic soil concentration, the soil water would contain less than 1 part per trillion (ppt) MGA. Again, one part per trillion is equal to 1 second in 32,000 years!

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[4] NADA 34-254 – MGA 100/200 Premixes and NADA 39-402 – MGA 500 Liquid Premix Type A Medicated Articles for heifers. Active ingredient: melengesterol acetate. Environmental Assessment and Finding of No Significant Impact. June 1996; August 1996. http://www.fda.gov/cvm/FOI/ea_gn.htm

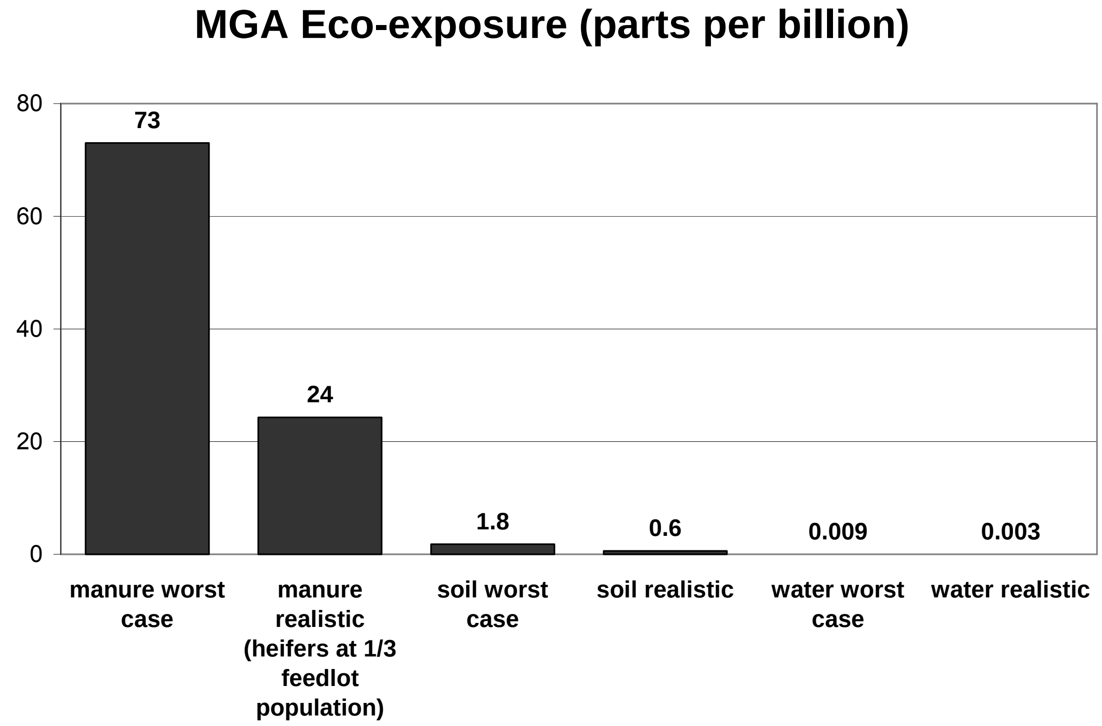

Figure 1. Estimated worst-case and more realistic environmental concentrations in various mediums.

Compare the 1.8 ppb MGA worst-case soil estimate with the eco-toxicology results. No effects were seen in earthworms kept for 28 days in soil containing 2,000 ppb MGA or in seeds or plants grown in soil containing 3,000 ppb MGA. While field runoff is calculated to contain less than 0.01 ppb MGA, no effects were observed in either of the aquatic species tested when exposed to 100,000 times or more of this worst-case exposure level. *Daphnia*, a small freshwater planktonic crustacean commonly used in testing aquatic toxicity, showed no effects when exposed for 48 hours to 2,000 ppb MGA. Goldfish exposed for 21 days in water containing 1,000 ppb MGA (the solubility limit of MGA in water) showed no ill effects.

And all of this ignores the facts that MGA is excreted mostly as metabolites of lower bioactivity; that both MGA and metabolites biodegrade in soils within days to months; and that MGA and metabolites in water are very rapidly degraded by sunlight (half-lives of 4 to 25 hours).

Eco-safety Assessment of Trenbolone Acetate (TBA)

TBA is administered to heifers and steers in feedlots at between 140 and 200 mg per animal. All of the TBA released into the animal from the ear implant is metabolized in the cow into less bioactive metabolites. Research indicates that the most abundant TBA metabolite excreted from cattle is 17 alpha trenbolone (17α–TB), with smaller amounts of 17 beta trenbolone (17β –TB) and glucuronide conjugates. Studies indicate that cattle waste contains roughly 10 times more of the 17α–TB metabolite than the 17β –TB.[5] Importantly, given its predominance in cattle wastes, the hormonal activity of 17α–TB is roughly 20 times lower than 17β –TB.

FDA considered a worst-case environmental exposure scenario in which it was assumed that all 200 mg of TBA from an animal is released as the 17α–TB metabolite over 66 days into 10 kg of waste per animal per day.[6] This would result in 660 kg (1,450 lbs) of manure containing 300 ppb of TBA metabolites. In comparison, actual field studies have found only 4 to 75 ppb of 17α–TB in fresh manure (0.5 to 4.3 ppb of 17β –TB), declining to 0 to 5 ppb after 4.5 months of storage.[7]

As is common practice on feedlots, the manure was applied to cropland at a rate of 15 tons per acre. Incorporation of manure with 300 ppb 17α–TB into the top 6 inches of soil results in a soil concentration of 5 ppb 17α–TB. Based on the degradation, solubility and soil sorbtion coefficients of 17α–TB, no more than 10 percent of this would be expected in soil runoff, or 0.5 ppb. Moreover, research shows that 17α–TB is readily biodegraded, with only 1 percent or less of the initial amount found in soils after 56 days. Based on this, a worst-case scenario finds only 0.1 ppb 17α–TB or less in the soil two months after it is applied.

A field study of stored liquid manure applied to cropland indicates soil concentrations of only 0.16 to 0.25 ppb 17α–TB immediately after application, and only 1 to 3 parts per trillion 17α–TB in the soil two months after manure application. The same study found only 3 to 11 ppt 17α–TB in soil one month after application of solid manure.

There is no indication these levels pose any threat to soil organisms or other wildlife. Even when added to soils at up to 150 ppb (30-fold higher than the worst-case scenario of 5 ppb), no effects were seen on soil microorganisms.

Estimating potential soil runoff concentrations using the 17α–TB levels found in the field study indicates very low soil runoff concentrations. For liquid manure, soil runoff would contain no more than 16-25 ppt 17α–TB one day after manure application; and no more than 1-5 ppt after one week. For solid manure, soil runoff would contain no more than 4 ppt 17α–TB immediately after application and 0.3-1.1 ppt after 26 days.

Effects in aquatic organisms have been reported in the literature starting at 17α–TB concentrations of about 10 ppt, which is within the expected range of possible soil runoff concentrations.[8] However, any soil runoff would be immediately and significantly diluted in the surface waters harboring such aquatic organisms to concentrations likely well below those seen to have any biological effects. In addition, the half-life of 17α–TB in water is less than a day, indicating rapid degradation.

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[5] Schiffer B, Daxenberger A, Meyer K, Meyer HHD. 2001. The fate of trenolone acetate and melengestrol acetate after application as growth promoters in cattle: Environmental studies. *Env. Health Perspect.* 109(11):1145-1151.

[6] NADA 138-612 Finaplix Ear Implant for feedlot heifers and steers. Active ingredient: trenbolone acetate. Environmental Assessment and Finding of No Significant Impact. April 1987; May 1987. http://www.fda.gov/cvm/FOI/ea_gn.htm

[7] Schiffer et al., op cit

[8] Jensen KM, Makynen EA, Kahl MD, Ankley GT. 2006. Effects of the feedlot contaminant 17α-trenbolone on reproductive endocrinology of the fathead minnow. *Env. Sci. Technol.* 40(9):3112-3117.

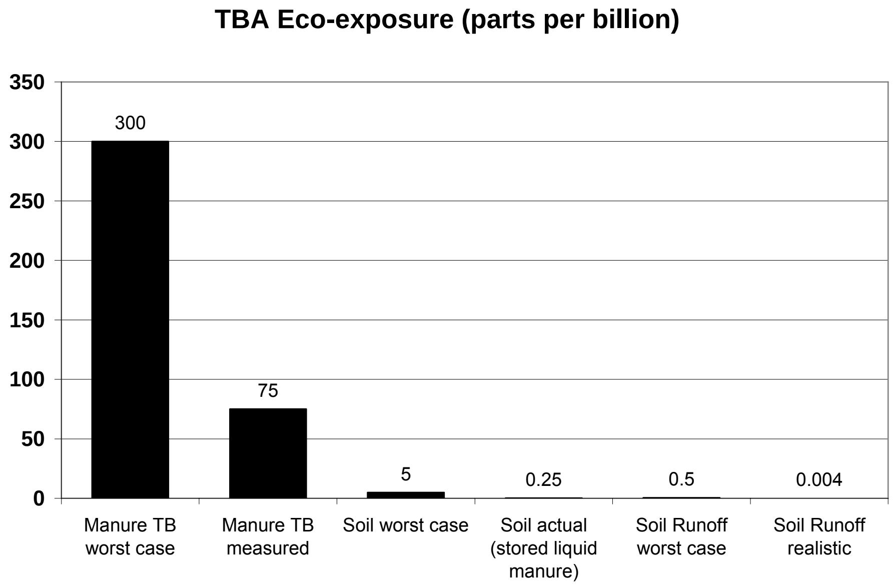

Figure 2. Estimated worst-case and measured environmental concentrations in various mediums.

Eco-safety of Zeranol

Zeranol is given to steers in feedlots via slow-release implants placed in the ear at a dose of 36 or 72 mg per animal. The zeranol is released over a 120-day period, so FDA considered a scenario in which 0.60 mg of zeranol per day is released into 27.3 kg of manure for 120 days.[9] This results in 3,270 kg of manure containing 72 mg of zeranol, for a manure concentration of 22 ppb zeranol.

If a 2-inch rainfall event occurred at this feedlot – assuming that each animal's 200-square-foot pen contained in the accumulated manure a total of 50.5 mg of the 72 mg zeranol (>2/3) – the maximum concentration of zeranol in the potential runoff from the feedlot would be 50 ppb.

Zeranol degrades to carbon dioxide ($CO_{2)}$ in manure with a half life of 56 days. After 120 days, the accumulated manure in the feedlot will contain only 12 ppb zeranol. After a further 20 days of degradation and zeranol-free manure accumulation (steers are commonly fed for 140 days yet zeranol will no longer be excreted after 120 days) the concentration of zeranol in the manure will decline further to 6.3 ppb.

In estimating soil concentrations, FDA considered that this 6.3 ppb zeranol manure would be applied to cropland at a rate of 13.6 tons per acre. After incorporation into the top 6 inches of soil, the concentration of zeranol would then be 0.09 ppb, or 90 parts per trillion.

Research shows that 45 percent to 58 percent of the zeranol will bind to soil. Assuming a 2-inch rainfall event and 50 percent binding of zeranol in the soil, the water run-off would contain only 0.2 ppt. This is a worst-case estimate as zeranol rapidly degrades in the environment. With its 90-

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[9] NADA 038-233 Ralgro implants for feedlot steers. Active ingredient: zeranol. Environmental Assessment and Finding of No Significant Impact. August 1994; November 1994. http://www.fda.gov/cvm/FOI/ea_gn.htm

day half life in soil, 90 ppt zeranol is reduced to less than 1 ppt after one year, which does not pose an environmental risk. Moreover, as zeranol-contaminated water moves through and across soil, it will encounter and bind to new soil.

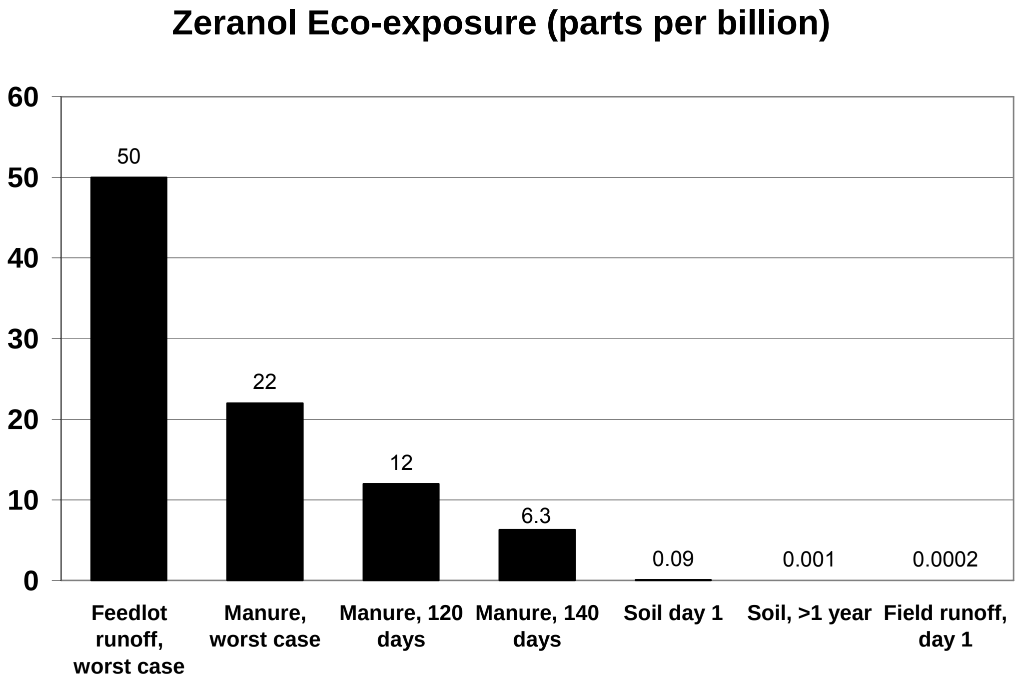

Figure 3. Estimated zeranol concentrations in various mediums (72 mg product).

Compare the 6-7 ppb worst-case estimate of zeranol in manure-incorporated soil with the ecotoxicology results. No effects at all were seen in earthworms exposed to soil containing 1,000 mg/kg of zeranol (1,000 ppm). This is more than 140,000 times the worst-case soil estimate and more than 7 million times levels realistically expected in the environment. No impacts were seen in corn, cucumber, pinto bean, soybean or wheat seeds at these same extremely high levels.

Additional Water Quality Protections in Feedlots and Animal Feeding Operations

In addition to the assurances of environmental safety that are part of the FDA approval process for cattle growth enhancement compounds, beef feedlots and other confined animal feeding operations (CAFOs) are required to adhere to a strict set of water quality protection measures in their design and operation. These are administered at the state level and include both federal and additional state-level environmental protection requirements.

The state of Texas is representative of these comprehensive state-level environmental regulations protecting water quality. Operators of Texas beef feedlots must submit a detailed, site-specific pollution prevention plan that is prepared in accordance with good engineering practices, including:

- All measures necessary to prevent and limit discharge of pollutants to surface and ground waters
- Detailed site maps with details of all:
  - pens, barns, manure storage areas, control facilities (including all water/waste retention control structures), land where manure/wastewater will be applied
- All water wells and surface waters located on-site or within one mile of the facility boundary
- Land application map, including all required buffer zones between surface waters
- Any and all ground water recharge features, which must be protected
- Documentation of all retention control structures and groundwater recharge areas by a licensed Texas professional engineer or licensed professional geoscientist
- All potential pollution sources, including manure, sludge, wastewater, dust, fuel, pesticides, land application of manure/wastewater, manure stockpiling
- Soil erosion

These extensive regulations and requirements allow direct discharge of wastes and/or wastewater only in the case of catastrophic condition, catastrophic rainfall event (100-year, 24-hour rainfall event for facilities built after 2004 or 25-year, 24-hour rainfall event for existing CAFOs).

The list of requirements for manure/runoff retention control structures is exhaustive, and all retention control structures (RCS) must be certified by a licensed professional engineer. These encompass their design, sizing, drainage area, storage volume relative to number of animals, minimization of uncontaminated precipitation/runoff collection, operation, and continual maintenance. Any manure stored for more than 30 days must be stored in the drainage area of an RCS to collect runoff. No storage of manure is allowed in the 100-year floodplain of surface waters.

Finally, all waste/manure land applications must follow strict guidelines on where and how the wastes can be applied, including buffer areas around surface waters, no application if ground is frozen or saturated, or during rainfall events. Wastes must not be applied at more than agronomic rates based on required soil testing and planned crop requirements. These regulations are even stricter if the CAFO is in a sole-source drinking water impairment zone.

In short, environmental control over residues of growth enhancing pharmaceutical products is inherent in the design and operation of modern beef feedlots and offers an assurance of minimal ecological impact.

Recent Studies and Concerns About Aquatic Impacts

Within the last decade, a number of environmental groups have suggested that the use of growth promoting hormones and pharmaceuticals in beef production may be inadvertently impacting aquatic communities. In part, these concerns arise out of findings that hormonally active compounds are released from municipal waste water treatment facilities into surface waters where they have altered fish reproductive development.

The amount of discharge from these municipal waste water treatment facilities is large and is sent directly into surface waters. It includes both natural human hormones as well as supplemental hormones from birth control pills and hormone replacement therapies. Thus, these situations are not directly comparable to the runoff from cattle feedlots and fields where cattle wastes are collected and applied to crop fields as fertilizer. However, they raise questions about possible impacts.

It must be stressed that current methodologies used in these studies are at the cutting edge of hormone detection and testing capabilities. There is still considerable question as to the accuracy and sensitivity of these methodologies.

For example, from 1999 to 2000, researchers with the U.S. Geological Survey conducted extensive testing of stream water from various monitoring stations and reported finding numerous reproductive hormones at fairly high frequencies (10 percent to 20 percent of samples).[10] However, the analysis was not based on validated assays (tests) and the accuracy and reliability of these methods remains an open question. Subsequent analysis indicates there may be many confounders to these data and assays.[11]

For example, concentrations of several synthetic hormones used only in human pharmaceutical products (used in contraceptives and hormone replacement therapies) were found by the USGS researchers at two rural monitoring stations at levels substantially higher than would be anticipated, given their lack of downstream proximity to a human wastewater treatment works or other expected source. One group of scientists subsequently suggested this difference may be due to interference of the test by natural organic materials in the water that could not be resolved by the analytical method used, resulting in a false positive. The take-home message is that studies addressing downstream and “local” steroid contamination from animal production units must use validated testing methods and valid sampling to assure the sample is reflecting the true source of the steroid(s).

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[10] Kolpin DW, Furlong ET, Meyer MT, Thurman EM, Zaugg SD, Barber LB, Buxton HT. 2002. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: A national reconnaissance. *Env.. Sci. Technol.* 36:1202-1211.

[11] Anderson PD, D’Aco VJ, Shanahan P, Chapra SC, Buzby ME, Cunningham VL, DuPlessie BM, Hayes EP, Mastrocco FJ, Parke NJ, Rader JC, Samuelian JH, Schwab BW. 2003. Screening analysis of human pharmaceutical compounds in U.S. surface waters. *Env. Sci. Technol.* 38(3):838-849.

Regardless, several groups have examined this issue in recent years and the results, while intriguing, are also reassuring.

In 2004, a group of university and EPA researchers examined fathead minnows from directly below the effluent outfall of a feedlot and compared them to minnows from a stream receiving manure-fertilized field runoff and minnows from a stream with no cattle production.[12] They reported finding differences in the ratios of various hormones in minnows from the upstream and downstream sites. However, they *did not* observe characteristics in any minnows indicative of exposure to environmental estrogens. As they stated, "we confirmed that all [minnows] collected were adults and that the reproductive stage of the gonads in males and females did not vary among sites." The water from a waste retention pond at the base of the feedlot exhibited hormonal activity in an ultra-sensitive test. But to what extent this was due to natural hormones in the waste or supplemental hormones from implants or feed-added MGA was not examined. Nor is it surprising that undiluted cattle waste would exhibit hormonal activity in the highly sensitive test used (monkey kidney cells genetically engineered to contain the human androgen receptor and the sensitive luciferase enzyme).

In 2002/2003, a group of EPA researchers examined water from the discharge drain of a cattle feedlot in central Ohio using the same ultra-sensitive assay (genetically engineered monkey kidney cells).[13] Indeed, the undiluted feedlot drain water occasionally registered hormonal activity. However, at other times it did not. For four of nine sampling periods, no differences were observed between feedlot drain water and water from upstream (575 meters) or downstream (381 meters) of the feedlot.

Most importantly, while roughly 50 percent of the water samples taken directly from the feedlot drain exhibited some hormonal activity in the ultra-sensitive test, at no time did any of the samples from 380 meters downstream ever exhibit elevated hormonal activity.

In short, while such research should continue to fully characterize and confirm the rapid degradation and low eco-transport of growth promoting pharmaceuticals, none of these findings are alarming or indicate a significant environmental threat.

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[12] Orlando EF, Kolok AS, Binzcik GA, Gates JL, Horton MK, Lambright CS, Gray LE, Soto AM, Guillette LJ. 2004. Endocrine-Disrupting effects of cattle feedlot effluent on an aquatic sentinel species, the fathead minnow. *Env. Health Perspect.* 112(3):353-358.

[13] Durham EJ, Lambright CS, Makynen EA, Lazorchak J, Hartig PC, Wilson VS, Gray LE, Ankley GT. 2006. Identification of metabolites of trenbolone acetate in androgenic runoff from a beef feedlot. *Env. Health Perspect.* 114(supp 1):65-68.

Land Use and Greenhouse Gas Emissions from Beef Production

There is considerable concern about the impact of agriculture – and meat production in particular – on land use, energy, and greenhouse gas emissions. In November 2006, the United Nations Food and Agriculture Organization (FAO) released a widely cited report examining this issue, ominously titled "Livestock's Long Shadow."[14] According to the report, global cattle-rearing generated more greenhouse gases (GHG) as measured in carbon dioxide equivalent, than transportation. However, data from the Environmental Protection Agency's (EPA) April 2007 report, "U.S. Inventory of Greenhouse Gas Emissions and Sinks," which contains data through 2005, indicates that U.S livestock grazing, feeding and manure managements systems are superior to those elsewhere in the world.

EPA data show that production of food animals overall in the United States contributes less than 2.3 percent of the total GHG emissions (measured in CO_2 equivalent). By comparison, fossil fuel combustion contributes approximately 80 percent of all U.S. GHG emissions.

According to EPA data, animal agriculture does not contribute significantly to the U.S. production of carbon dioxide. The U.S. production of food animals contributes to methane emissions in two primary ways: enteric fermentation and manure management. EPA data show animal agriculture accounts for about 28 percent of U.S. methane emissions (measured in CO_2 equivalents). Notably, overall methane emissions account for less than 8 percent of total GHG emissions, Finally, according to the EPA, animal agriculture contributes only 2 percent of nitrous oxide emissions measured in CO_2 equivalents.

Although the EPA data tell the true story of U.S. animal agriculture, the worldwide numbers reported by the U.N. FAO are widely circulated and quoted in the media. Any assessment of the environmental impact of beef production systems and technologies must therefore account these minimal emissions and compare them with alternatives.

In the case of beef, there are two major post-weaning production paradigms in the U.S. and Canada: cattle feedlots utilizing a mixed ration of grain, forage (hay, alfalfa, etc.) and growth promoting technologies vs. pasture- or grass-based finishing. Both systems have their respective advantages and disadvantages, but the two have significantly different environmental impacts. Beef produced from cattle in feedlots with the help of growth enhancing products requires significantly less total land (including feed crops) and creates substantially fewer greenhouse gasses in the process.

An Iowa State University (ISU) model comparing the profitability of various niche beef production methods helps illustrate the relative magnitude of differences in resources and environmental costs.[15] This economic model was funded by the Leopold Center for Sustainable Agriculture at ISU in order to help inform farmers who are considering transitioning to "alternative" beef production methods such as "organic" and "natural."

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[14] U.N. FAO. 2006. Livestock's Long Shadow: Environmental issues and options. Available online: http://www.virtualcentre.org/en/library/key_pub/longshad/A0701E00.pdf

[15] Acevedo N, Lawrence JD, Smith M. 2006. Organic, Natural and Grass-Fed Beef: Profitability and constraints to Production in the Midwestern U.S. Report to Leopold Center for Sustainable Agriculture, Iowa State University. http://www.iowabeefcenter.org/content/Organic_Natural_Grass_Fed_Beef_2006.pdf

The model farms assumed equal herd size (100 cows), equal pre-weaning mortality, equal corn yields (150 bushels per acre), equal grass productivity and well-managed pastures for fall, spring and summer. It then adjusted land needs and productivity using the Cornell Net Carbohydrate and Protein System (CNCPS) model. The CNCPS was "developed to predict requirements, feed utilization and nutrient excretion for dairy and beef cattle in unique production settings," and is well regarded in examining the resource costs and efficiencies of the various beef production systems as well as the impact of using growth promoting hormones.

It is important to remember that the ISU model parameters likely *under*estimate the benefits of grain-feeding beef cattle with the aid of growth promoting hormones. Why? The ISU model assumes conventional grain-fed cattle are fed in a feedlot for 303 to 329 days before harvest, whereas most cattle spend no more than 220 to 240 days in a feedlot prior to harvest. This means that typically, beef cattle spend 20 percent to 30 percent less time in a feedlot than modeled in the ISU comparison. So this comparison is likely a worst-case scenario that favors the grass-finishing system.

Environmental Cost Comparison

While the ISU group examined five production systems (organic grass-finished, organic grain-finished, natural grass-finished, natural grain-finished, and conventional grain-finished utilizing growth promoting hormones), here the resource costs for just three production systems will be examined: organic grass-finished, natural grain-finished and conventional grain-finished with growth promoting hormones.

The modeled grass-finishing system assumes small frame cattle, as recommended for grass-finishing. This means that they have smaller cows to feed, a smaller calf weaned, and a smaller animal sold for harvest. The grain-finished model systems assume medium-framed animals, accounting for the differences in cow size and calf weights at weaning. Both assume a spring-born calf weaned on November 1. The calves in the grass-finishing system remained on a diet of pasture and hay while the grain-finished calves were fed on pasture, hay and corn. Each of the two scenarios assumed that there were 100 calves born, 3 percent death loss, 20 heifers kept for replacements and 77 animals finished (48 steers and 29 heifers). A grass-based finishing operation requires 660 acres of pasture and hay, whereas the conventional grain-finishing system requires 365 acres of pasture, hay and corn.

Table 2. Model results for starting weight, days on feed, final weight and carcass weight for the three systems.

	Organic grass-fed	**Natural grain-fed**	**Conventional grain-fed**
Starting weight, lbs	425	475	475
Days on feed	366	329	303
Post weaning avg. daily gain (ADG)	**1.65**	**2.36**	**3.06**
Feed:Gain (FTG), dry matter	10.99	7.12	6.22
Marketing date	2-Nov	26-Aug	31-Jul
Final weight, lbs	1,029	1,251	1,401
Dressing percent	61%	63%	63%
Carcass weight, lbs (beef yield)	**623**	**782**	**876**
Total system beef production, lbs	**47,971**	**60,214**	**67,452**

Land Costs of Beef Finishing Systems

The three systems return different amounts of beef based on the differing performance of the animals under the different production paradigms, which, in turn, affects the amount of resources used per pound of beef produced. The biggest factors in resource use efficiency are:

- The 11 percent smaller frame size of the grass-fed animals (and subsequently lower finished weight)
- The 20 percent longer finishing period (days on feed) in the grass-fed system
- The 80 percent larger land area needed to feed cows due to lower energy density of grass versus grain

To calculate land costs per pound of beef produced in the three model farms, multiply the total farm acreage by the number of days on feed, then divide this number by the total pounds of finished beef produced. This process is demonstrated in the following two steps:

1. For the grass-fed system, 100 cows on 660 acres for 366 days on feed:

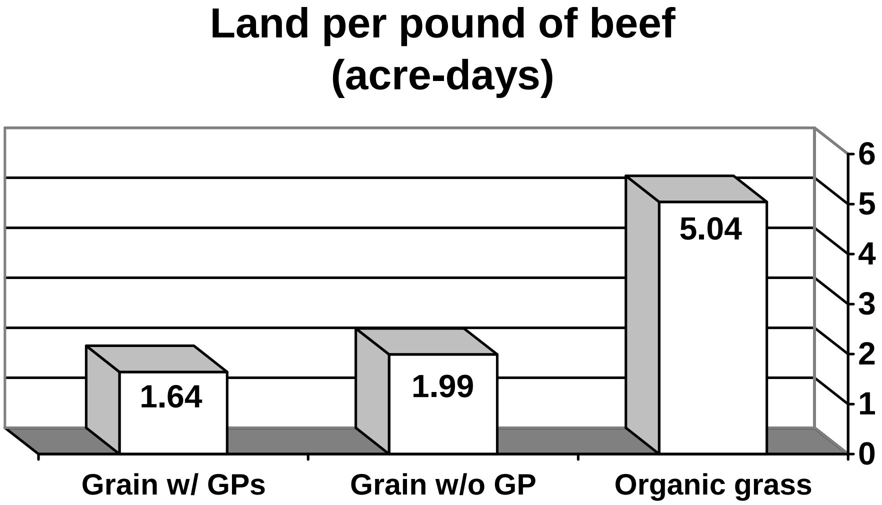
660 acres X 366 days on feed = 241,560 acre-days.

2. The average grass-fed organic cow yielded a carcass weight of 623 pounds. Multiplied by the 77 animals sold for harvest, the total beef yield was 47,971 lbs. The calculation below demonstrates how this yields land use per pound of beef produced.

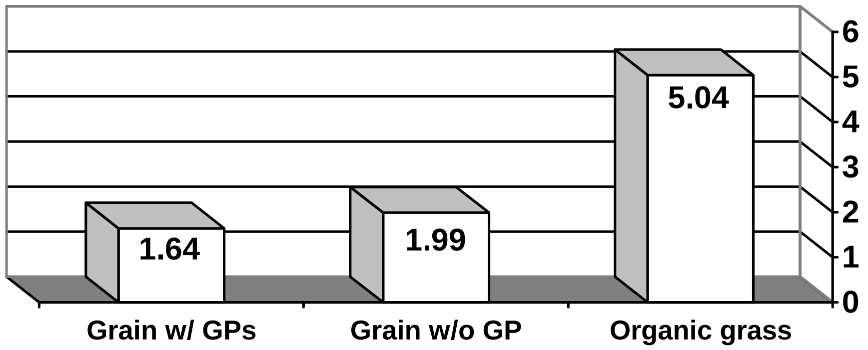
241,560 acre-days ÷ 47,971 lbs beef = 5.04 acre-days/ 1 pound finished beef.

Table 3. Land use costs per pound of beef for the three finishing systems

	Organic grass-fed	**Grain-fed without growth promoters**	**Grain-fed with growth promoters**
Land use (acre-days) per pound	5.04	1.99	1.64



Land per pound of beef (acre-days)



Thus, grain-finished beef produced using growth promoting pharmaceuticals is three times more land efficient than organic grass-finished beef, requiring only one-third of the land per pound of beef in the ISU model. When compared to "natural" grain-finished (i.e., fed in feedlots but without growth promoting pharmaceuticals), the conventional method is 20 percent more land efficient. Thus, growth promoting pharmaceuticals conserve considerable land for other purposes by allowing a substantial increase in land- use efficiency over grain-finishing alone.

This reality is reflected in far more than just models. Individual trials on growth promoting implants report increases in average daily gain (ADG) from -5 percent to +38 percent, with an average increase in ADG of nearly 14 percent. Conversely, the individual trial effects of growth promoting implants on the feed to gain ratio (FTG) range from a 7.7 percent to nearly 23 percent improvement, with an average improvement of 8.8 percent.[16] These are substantial gains in feed use efficiency over grain-based finishing alone that translate into reduced feed requirements and, thus, substantial gains in land use for other purposes.

Habitat Conservation Quotient

If put in terms of a "farm footprint," the use of growth promoting hormones allows a 20 percent reduction in land needed for beef finishing over grain-based finishing alone. And, compared to grass-based cattle production, grain-finishing with growth promoting implants increases land use efficiency three-fold.

In a very real sense, grass finishing of beef is an efficient use of farmland less suited for growing feed crops. There are several regions on the globe where grass production is arguably the best, most productive and most environmentally sensitive use of farmland. In such instances, grass-based beef production is a good use of such farmland, especially given the growing consumer demand for grass-finished beef. However, in farming areas with good to excellent arable cropland where grass production would represent a less efficient use of the land, grain finishing represents a better, more efficient use of this farmland resource.

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[16] Lawrence JD, Ibarburu MA. 2006. Economic analysis of pharmaceutical technologies in modern beef production. www.econ.iastate.edu/faculty/lawrence/pharmaeconomics2006.pdf

Finally, grain finishing with the aid of growth promoting implants and other growth enhancing pharmaceuticals represents arguably the best, most efficient use of the total farmland resource.

It is imperative that we use each and every acre of farmland to its best and most productive use given the:

- Growing world population
- Increased per-capita demand for beef and other high-quality animal proteins
- Severely limited land area on which to produce food, feed and fiber for humanity (currently estimated 40 percent of total world land area)
- Increased pressures to conserve natural and biodiverse habitats for nature

To that end, we should view each system in terms of its habitat conservation quotient, as illustrated in Figure 6. While utilizing grass and grazing lands for beef production converts a human inedible resource into a nutritious edible protein, grain-finishing utilizes cropland in a fundamentally land-conserving manner, allowing more land to be devoted to other human uses or allowing humanity to conserve wildlife habitats that would otherwise be converted to farmlands.

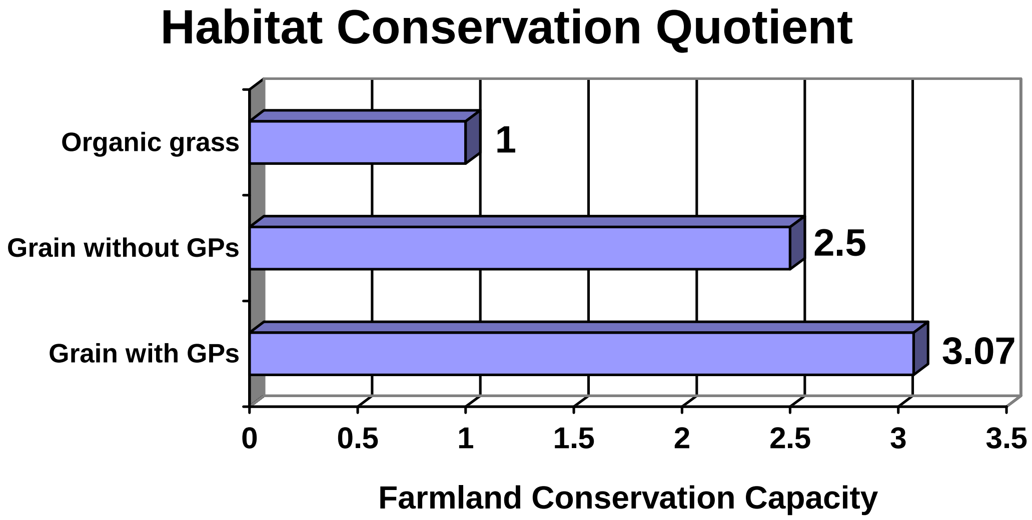

Figure 6. Relative land conservation capacity

Greenhouse Gas Emissions Associated with Beef Production

A second key metric in assessing the eco-impact of beef production is the emission of greenhouse gases (GHGs) into the atmosphere. GHGs come from a number of sources:

- All livestock production resulting in the release of carbon dioxide from the respiration of the animals themselves
- Secondary methane (CH_4) production from animal waste decomposition and (in the case of ruminants) enteric fermentation
- Emissions of CO_2 from the production of synthetic nitrogen fertilizers used to grow livestock feed grain
- Nitrous oxides (N_2O) production from farmland and manure management

According to the U.S. Environmental Protection Agency (EPA), U.S. agriculture accounted for 7 percent of total U.S. CO_2 equivalent greenhouse gas emissions in 2005.[17] Roughly half of this (~15percent of agriculture's share) is from methane emissions related to manure and enteric fermentation and half from nitrous oxides from crop and grasslands. Beef production accounts for roughly 30 percent of the 7 percent of the GHGs attributed to agriculture in general, and just 2 percent of overall GHG emissions.

Assessing greenhouse gas emissions from different livestock production systems can be a complex exercise because numerous factors affect the production of these gases in beef cows, including increased production of methane with decreasing dietary energy density and regional differences in greenhouse gas production relating to pasture quality and crop production methods.

These factors and accounting have been extensively studied as part of the United Nations Intergovernmental Panel on Climate Change (IPCC).

1. CO_2 from Respiration

According to the Kyoto protocol, carbon dioxide emitted due to livestock respiration is not considered to be a net source of CO_2 emissions because the emitted CO_2 itself came from plant matter created through the conversion of atmospheric CO_2. According to the U.N. FAO, however, beef and buffalo emit nearly 2 billion tons of CO_2 annually via respiration, and each cow emits roughly 3.8 lbs of CO_2/year by respiration for each pound of live weight.[18] Using this number, we can roughly estimate the amount of respirated CO_2 for our three finishing systems with the following formula:

[(Final live weight + Starting weight) ÷ 2] x 3.8 x (Days on feed, i.e., percent of 1 full year) = CO_2 emitted/animal/year
(CO_2 per animal) x 100 = total herd emissions

We then divide the estimated herd CO_2 emissions by the total pounds of finished beef from the 77 sold animals to calculate respiration CO_2/lb beef produced.

Table 4. Respiration CO_2

	Organic Grass-fed	Natural Grain-fed	Conventional Grain-fed
Average live weight, lbs	727	863	938
Per-cow CO_2 from respiration, lbs	2,768	2,951	2,958
Herd CO_2 from respiration, lbs	276,800	295,100	295,800
CO_2 emissions from respiration per pound beef, lbs	**5.77**	**4.9**	**4.39**

As shown in Table 4, grass-fed beef results in 30 percent greater CO_2 emissions per pound of beef from respiration compared to modern grain-fed finishing. The use of growth promoting technology results in about a 10 percent reduction in per-pound respiration CO_2 emissions compared to not using these inputs. However, CO_2 from respiration is such a small source that the EPA does not even account for it.

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[17] EPA. 2007. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005. http://www.epa.gov/climatechange/emissions/usinventoryreport.html

[18] U.N. FAO. 2006. op cit page 96, Table 3.6.

2. CO_2 from Nitrogen Fertilizer Production (Grain-fed System Only)

Because no synthetic nitrogen fertilizers were applied to organic pastures, there are zero CO_2 emissions from fertilizer in the grass-finished system.

According to the UN FAO, the production of nitrogen fertilizer for animal feed accounts for more than 40 million tons of CO_2 emissions per year. FAO calculates CO_2 emissions based on the energy needed to produce a ton of fertilizer and estimates of carbon emissions per terajoule of energy involved in the nitrogen fixation process. According to the FAO calculations, about 2.5 lbs of CO_2 are emitted per pound of nitrogen fertilizer manufactured. Using a reasonable estimate of 150 lbs of nitrogen to produce the 150 bushel/acre corn yield assumed in the Iowa State model, we can calculate CO_2 emissions from feed production per animal and then convert to "per pound of beef" emissions estimates.

In the ISU model, the conventional grain-finished beef animals each consumed 1,780 lbs of corn silage and 79.1 bushels of corn over the full finishing process. At 150 bu/acre, corn will yield about 20 tons of corn silage at 65 percent moisture, so 1,800 lbs of corn silage represents about 5 percent of an acre's harvest. The ~80 bushels of corn grain represent 53 percent of an acre's harvest. Combined, they represent roughly 60 percent of the 150 lbs of nitrogen fertilizer applied, which is 90 lbs. At 2.5 lbs of CO_2 per pound of nitrogen fertilizer, this totals 225 lbs CO_2 emissions per cow.[19]

After multiplying by 100 (total cow herd) and dividing by the total beef produced (67,452 lbs), we find that conventional grain-fed beef results in 0.33 pound of CO_2 equivalent GHG emissions per pound of beef. For the "natural" grain-finished cattle, it works out to 0.35 lbs of CO_2 equivalent emissions per pound of beef.

3. Methane from Digestion (Enteric Fermentation) and Cattle Manure

Another GHG we must address is methane produced as part of the natural biology of ruminant animals like cows. Unlike swine and poultry, ruminant animals harbor a bacterial flora in their multi-chambered rumen that generates significant amounts of methane as a natural part of their fermentation of plant fibers into digestible sugars. Because methane is considered to be 23 times more powerful as an atmospheric GHG, each pound of methane is equivalent to 23 pounds of CO_2. As you will see, methane emissions account for a significant share of the 2 percent of greenhouse gas emissions from beef production.

One of the largest factors affecting methane production in cattle is the quality of the feed. Higher quality feeds produce less methane than lower quality feeds. Thus, a diet higher in grain will result in less methane emissions. According to the recently revised UN IPCC Tier 2 estimates for North America, grazing cattle will produce 110 lbs of methane per head per year whereas grain-finished cattle in feedlots will produce only 57.2 lbs.[20]

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[19] This excludes the 1,555 lbs of corn gluten feed produced as a byproduct of ethanol wet-milling. No reliable estimates for CO_2 emissions per ton or lbs of corn gluten feed could be found. However, as the rest of the calculations show, the other corn feed accounts for less than 5 percent of total CO_2 equivalent emissions, so this omission does not substantially impact the results.

[20] U.N. FAO, 2006, op cit, Table A3.1, page 385. North America "Grazing" EF of 50 kg methane/head/year vs. "Industrial" of 26kg/hd/yr. There are 2.2 lbs in 1 kilogram.

In addition to the enteric fermentation, we must account for manure methane emissions, estimated by the IPCC Tier 2 at 2.2 lbs per head per year for grass-finished cattle and 20.9 lbs per head per year for grain-finished cattle.[21] Because of methane's greater warming power as a greenhouse gas, these methane emissions are equivalent to 1,800 and 2,600 lbs of CO_2 per cow per year. (See Table 5)

Table 5. Methane Emissions

	Grass-finished	**Grain-fiinished**
Enteric fermentation emission	110	57.2
Manure CH_4 emissions	2.2	20.9
Total methane emissions estimates per head per year, lbs	**112.2**	**78.1**
CO_2 equivalent methane emissions per head per year	**2,580**	**1,796.3**

To calculate the CO_2-equivalent GHG emissions per pound of beef, we need to account for the different finishing lengths (303 days for conventional feedlot, 329 days for "natural grain-finished" and 366 days for organic grass-finished) and divide this by the total pounds of beef produced. (See Table 6)

Table 6. Estimated CO2-equivalent emissions

	Grass only	**"Natural" feedlot**	**Conventional feedlot**
CO_2 equivalent emissions per head at harvest, lbs	2,586	1,619	1,491
CO_2 equivalent emissions per herd, lbs	258,600	161,900	149,117
CO_2 equivalent methane per pound beef produced	**5.39**	**2.69**	**2.21**

Greenhouse Gas Emissions Totals

The CO_2 equivalent GHG emissions per pound of beef from these three sources can now be totaled. (See Table 7) As can be seen in Figure 7, organic grass-fed beef results in more than 60 percent more CO_2-equivalent GHG emissions per pound of beef from these three sources than conventional beef production. Growth promoting hormones account for fully 25 percent of the emissions reductions.

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[21] U.N. FAO, 2006, op cit, Table A3.2, page 387. "North America" EF of 9.5 kg methane/head/year was chosen to represent grain-fed feedlot production because the vast majority of U.S. beef production is feedlot. "China" and "S. America" EF of 1 kg methane/head/year was chosen to represent grass-fed production because most beef in these regions is grass pastured.

Table 7. CO_2 equivalent emissions per pound of beef

	Grass only	"Natural" feedlot	Conventional feedlot
Respiration	5.77	4.9	4.39
N fertilizer use	0	0.35	0.33
Methane from enteric fermentation and manure	5.39	2.69	2.21
Total CO_2 equivalent emissions per pound of beef	**11.16**	**7.94**	**6.93**

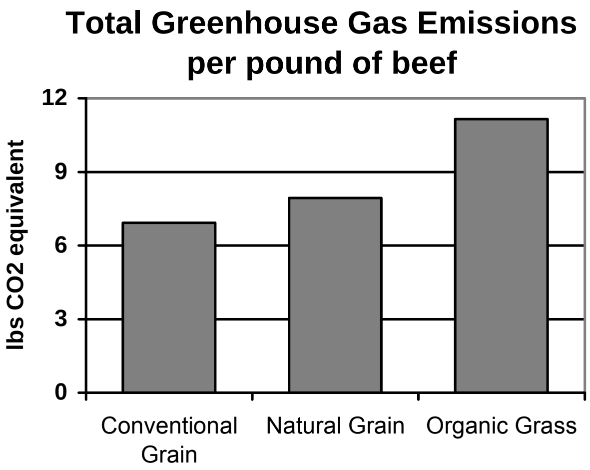

Figure 7. Greenhouse gas emissions per pound (excluding nitrous oxides)

4. N_2O from Crop and Manure Management.

The one aspect of greenhouse gas emissions not yet accounted for in this analysis is nitrous oxide, or N_2O. While this is perhaps the most significant GHG from the 2 percent attributable to beef production, accounting for up to half of the total greenhouse gases associated with all aspects of beef production, it is also the trickiest to estimate. N_2O is released from all agricultural land, both cropland and grass and grazing lands, and varies considerably based on a multitude of factors, including soil type, fertilizer applications, crop/plant growth, moisture levels, soil organic carbon, rainfall, temperature, and more. Because of this inherent and large variability, it is not possible to apply a simple, generalized "N_2O factor" to different production systems.

However, a group of researchers (Colorado State University, Texas A&M, and U of Hamburg) has been evaluating GHG emission between different beef production systems using sophisticated computer models and specific location parameters to gain insight into N_2O dynamics.[22] Their studies have shown that, of total CO_2-equivalent GHG emissions from beef production, 48 percent are from N_2O (all sources – animal manure, crop fertilization with nitrogen, legume and waste using IPCC 2001 factors), 41 percent are from methane (40 percent enteric, 1 percent manure), and 11 percent are from fuel CO_2 (both fuel and fertilizer). The cow-calf phase of production emits 75 percent of beef system GHGs, with emissions of just over 16 kg CO_2-

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[22] Johnson DE, Phetteplace HW, Seidl AF, Schneider UA, McCarl BA. 2003. Management variations for U.S. beef production systems: Effects on greenhouse gas emissions and profitability. 3rd International Methane and Nitrous Oxide Mitigation Conference. Beijing, China. http://www.coalinfo.net.cn/coalbed/meeting/2203/papers/agriculture/AG047.pdf

equivalent GHG per kg of product. This is about twice that of the stocker phase, and nearly threefold that of the feedlot phase, for a total of 22 kg GHG/kg product. They report that these ratios change little during the different beef production scenarios.

Of the five scenarios modeled in the ISU research, the system with the lowest N_2O emissions per kg of product was the intensive grazing and direct placement of calves into a feedlot. As they stated, “the sooner [calves] were placed in the feedlot, the lower the overall GHG/kg product.” So, while N_2O emissions are a major GHG in beef production, there do not seem to be major differences between production systems and what differences there are indicate that feedlot systems that finish animals more rapidly have the lowest N_2O emissions.

Environmental Conclusions

In sum, using a model system endorsed by sustainable agriculture advocates and the emissions factors stipulated by the United Nations Intergovernmental Panel on Climate Change, we find that organic grass-fed beef production requires three times more land and results in 60 percent more greenhouse gas emissions (excluding N_2O) compared to grain feeding with the aid of growth promoting hormones.

While this is not an “indictment” of grass-based beef production, as cattle efficiently turn a human inedible resource (grass) into a highly valuable and nutritious edible product, it clearly illustrates that modern feedlot beef production and growth promoting hormones both offer significant environmental advantages. The synergistic combination of grain-feeding in feedlots and growth promoting hormones and ionophores allow for the production of considerably more beef per acre of land and result in significantly less greenhouse gas emissions per pound of beef.

This reality should be taken into account by policy makers and the public as we struggle to meet the challenge of providing for the dietary wants and needs of humanity while having as little impact on the environment as possible.