The Environmental Safety and Benefits of Growth Enhancing Pharmaceutical Technologies in Beef Production

By Alex Avery and Dennis Avery
Hudson Institute
Center for Global Food Issues

Executive Summary

Growth promoting hormones are a key component of North American beef production. Their use over the past 50+ years (since 1956) has proven beneficial not only to beef producers, but to consumers and the environment, who 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 that has examined their use and the resulting beef products have found them to be both safe and wholesome, helping to produce an overall leaner beef supply with minimal residues of no practical health consequence. This assessment is shared not only by the Food and Drug Administration of the United States and Health Canada, but also by the Codex Alimentarius Committee of the World Trade Organization, the Food and Agriculture Organization of the United Nations, the World Health Organization, 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 natural, three synthetic. 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. 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 waste, runoff from cattle feedlots, and runoff from land on which the waste has 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 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-based beef production system using an economic/production model created by scientists at Iowa State University shows that growth promoting hormones and ionophores decrease the land required to produce a pound of beef by two thirds, with fully one fifth of this gain resulting from growth enhancing pharmaceuticals. Whereas grass-based organic beef requires more than 5 acre-days to produce a pound of beef, less than 1.7 acre days are needed in a grain-fed feedlot system using 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 fully 25 percent of the emissions reductions.

In short, growth promoting implants safely and responsibly allow humanity to produce more beef from less feed, using less land, and creating less waste.

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.

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 animals' ear. 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, there is no incentive for producers to "overdose" an animal on hormones. Each implant contains the optimal dose for maximum economic return, and administering simultaneous implants would have little impact on further weight gain. It would only waste money. This economic reality, coupled with the USDA's annual monitoring program, safeguards the system and ensures that hormones are used properly and safely.

Third, the doses are low. The science indicates that use of supplemental hormones in cattle has only a miniscule impact on hormone levels in beef – well below the natural hormone levels in beef or the amounts produced naturally in our own bodies. According to the US Department of Agriculture (USDA), a person would need to eat over 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 a half-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]

The whole world's health experts say beef hormones are safe, not just those in the United States and Canada. So do the World Health Organization (WHO) and other European scientific bodies. The Joint Expert Committee on Food Additives of the World Health Organization and United Nations' Food and Agriculture Organization (WHO/FAO Expert 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 Acceptable Daily Intake (ADI) of estradiol for a 75 pound child established by the WHO/FAO Expert Committee. (See "ADIs Explained")

---

[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.

And don't forget that our own bodies produce these same hormones every day in amounts a hundred times or more higher than found in beef. A pound of beef raised using 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 produced by a pregnant woman.

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. This issue is at the heart of the EU's justifications for not allowing the sale of U.S. and Canadian beef to European consumers since 1989, a long-running and bitter trade dispute. The only way that the EU has been able to concoct enough theoretical risk to even remotely justify to the World Trade Organization (WTO) their ban on the sale of North American beef in Europe has been to give cattle three- and 10-fold doses of the synthetic hormones and then declare that U.S. regulators cannot guarantee that such misuse isn't happening. (There is a complete lack of any evidence of such misuse in annual USDA monitoring). Even with these unlikely overdoses, hormone residues exceed the ADIs set by the WHO/FAO Expert Committee only in cow livers, not any other edible tissues. Despite this, the European Commission has maintained its prohibition on the sale of U.S. and Canadian beef based on a group of studies collectively called the "Copenhagen Assessment."[4]

The British government's Sub-Group of the Veterinary Products Committee estimated a "worst-case" exposure to residues of TBA (the synthetic hormone that mimics testosterone) based on the maximum amount the Sub-Group could extract from tissues following proper use of TBA. The resulting exposure estimate didn't exceed half of the conservative ADI for children set by the WHO/FAO Expert Committee. The highest TBA residue they found in muscle and fat translates into a pound of hamburger containing only 2.4% of the WHO/FAO Expert Committee's ADI for children. An extensive review of the world scientific literature on hormone metabolism and toxicity in humans can be obtained from both the Food Research Institute and the Sub-group of the Veterinary Products Committee.[5]

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;

---

[4] *Acta Pathologica Microbiologica, Microbiologica et Immunologica Scandinavia*, Supplementum no. 103, vol. 109, 2001.
[5] Doyle ME. 2000. Human safety of hormone implants used to promote growth in cattle: Scientific literature review. Food Research Institute, University of Wisconsin. Available at: http://www.wisc.edu/fri/briefs/hormone.pdf ; and, Review of the Scientific Committee on Veterinary Measures relating to Public Health, Report 30, April 1999. http://ec.europa.eu/food/fs/sc/scv/out21_en.pdf

• **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 (ADIs) Explained

ADIs are the dose of a substance experts believe is totally safe to consume each day for a lifetime. They 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 per 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.)

Below is a chart listing 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 even five 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)	**1.43%**
Progesterone	30 µg	1,050 µg	2,100 µg	(100 µg/lb)	**4.76%**
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)	**2.38%**
TBA	0.02 µg	0.7 µg	1.4 µg	(8 ng/lb)	**0.57%**
Zeranol	0.5 µg	17.5 µg	35 µg	(90ng/lb)	**0.26%**

Eco-Safety of Growth Enhancing Pharmaceuticals

The environmental safety of growth enhancing supplemental hormones is examined and established as an integral part of the U.S. Food and Drug Administration's (FDA) approval process. The FDA's Center for Veterinary Medicine must issue a Finding of No

Significant Impact (FONSI) 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 impacts, including expected environmental concentrations, exposure estimates based on chemical properties and fate data, and eco-impact assessments based on indicator organism toxicity testing.

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 physiology, pharmacology, and toxicology of these three natural hormones 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%) as the non-estrogenic metabolite 17-alpha estradiol.

The 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 the 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, are released into the environment in amounts well within natural levels, and 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 (prior to finishing), where the waste is deposited on pasture/grasslands. Or they are finished in feedlots, where the waste is 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:

- the propensity of the chemical to bioaccumulate in animals
- concentrations of product and/or metabolites in cattle waste
- the 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
- and potential toxicity to aquatic organisms.

In all cases, after examining the data for metabolism, excretion, degradation, and runoff potential, the FDA has determined that the use of the three synthetic 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 waste is collected and applied to crop fields as fertilizer as per existing regulations regarding the protection of surface waters.

In examining the environmental risk, the FDA considered a worst-case environmental exposure scenario.[6] 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 un-degraded (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 high 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 one second in 32 years or one inch in 16,000 miles)

It is important to note that this "worst-case" estimate is significantly higher than would be expected under most real-world conditions. For one thing, most cattle in feedlots are not heifers, but are steers – and steers are not given MGA. Thus, assuming that heifers make

[6] 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

up fully one third of the cattle population at a feedlot, the MGA concentration would be diluted by 2/3rds down to 0.6 ppb.

Most important, 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 one second out of 32,000 years!

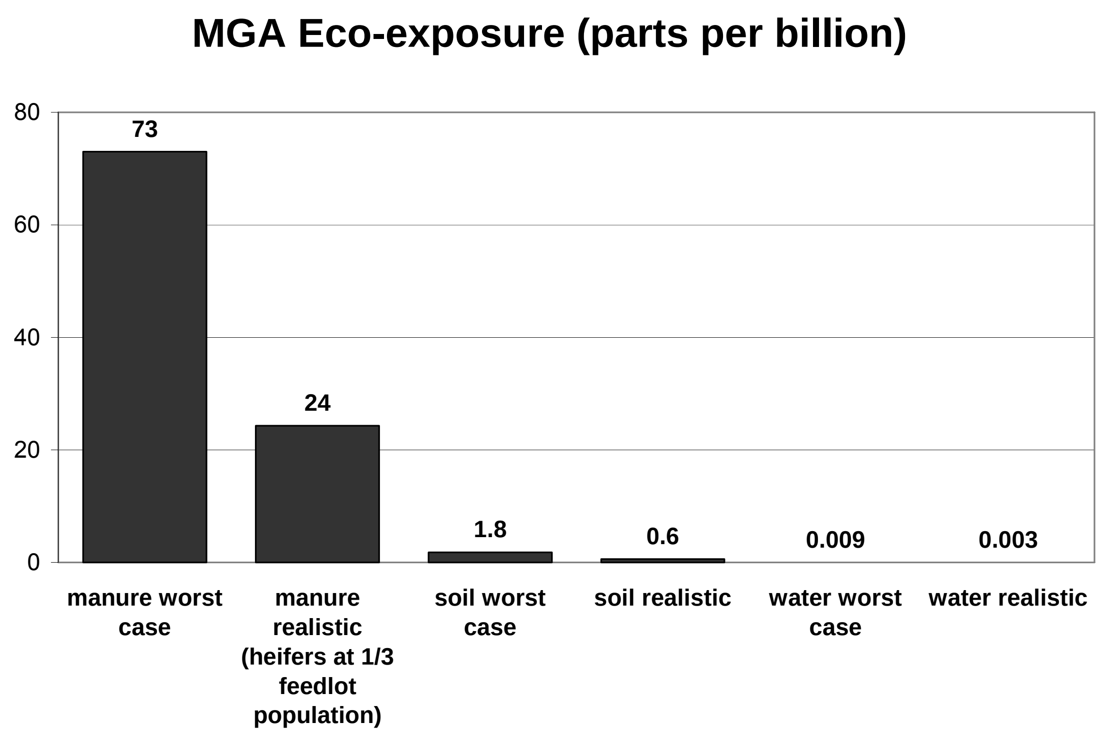

Figure 1. Estimated worst-case and more realistic environmental concentrations in various medium.

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 fact that MGA is excreted mostly as metabolites of lower bioactivity; that both MGA and its metabolites biodegrade in soils within days to months;

and MGA and metabolites in water are very rapidly degraded by sunlight (half-lives[7] of 4 to 25 hours).

Eco-safety assessment of Trenbolone Acetate (TBA)

TBA is administered to heifers and steers in feedlots at between 80 and 200 mg per animal. All of the TBA released into the animal from the ear implant is metabolized in the steer or heifer 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.[8] Given its predominance in cattle waste, it is important to note that the hormonal activity of 17α–TB is roughly 20 times lower than 17β –TB.

The FDA considered a worst-case environmental exposure scenario in which it was assumed that an animal is dosed at 200 mg of TBA and that all 200 mg is excreted from an animal as the 17α–TB metabolite over 66 days into 10 kg of waste per animal per day.[9] 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.[10]

As is common practice in feedlots, the manure was assumed to be collected and applied to cropland at a rate of 15 tons per acre. Incorporation of manure with 300 ppb 17α–TB into the top six 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 2% 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 2 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 1-3 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 that 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.

---

[7] A "half-life" is the time it takes for half of the amount of a substance to degrade.
[8] 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.
[9] 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
[10] Schiffer et al., op cit

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.[11] 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.

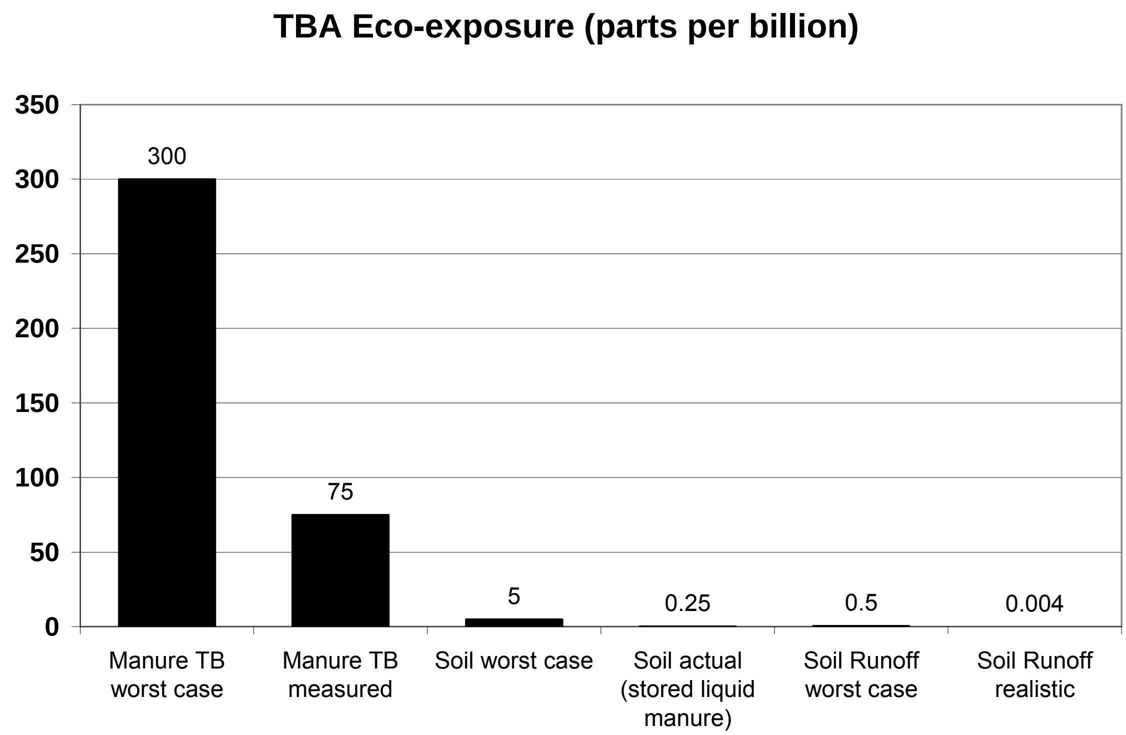

Figure 2. Estimated worst-case and measured environmental concentrations in various medium.

Eco-Safety of Zeranol

Zeranol is given to steers in feedlots via slow-release implants placed in the ear at a dose of 36 to 72 mg per animal. Most animals are dosed at the lower level, so the FDA's consideration of a scenario in which all animals are dosed at 72 mg is a worst-case assessment. All 72 mg of zeranol was assumed to be released over the 120 days (0.6 mg

[11] 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.

of zeranol per day) into 27.3 kg of manure per day for 120 days.[12] 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 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 in feedlots for 140 days yet zeranol will no longer be excreted after 120 days) the concentration of zeranol in the manure will fall further to 6.3 ppb.

In estimating soil concentrations, the FDA considered that the manure containing 6.3 ppb zeranol was 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 will then be 0.09 ppb, or 90 parts per trillion.

Research shows that 45 to 58 percent of the zeranol will bind to soil. Assuming a two inch rainfall event and 50 percent binding of zeranol in the soil, the water run-off will contain only 0.2 ppt zeranol. This is a worst case estimate as zeranol rapidly degrades in the environment. With its 90-day half life in soil, 90 ppt zeranol is reduced to less than 1 ppt after one year, a level that does not pose an environmental risk. Moreover, as zeranol-contaminated water moves through and across soil, it will encounter and bind to new soil.

[12] 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

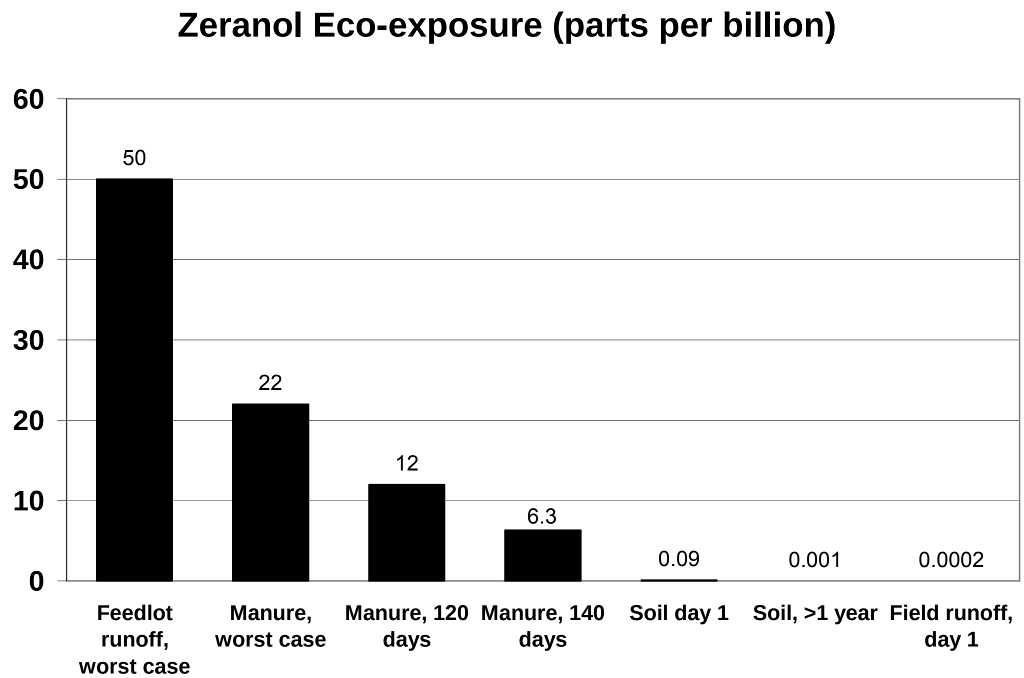

Figure 3. Estimated zeranol concentrations in various medium using the worst-case estimate based on 72 mg dosing of all animals.

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 1000 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.

Eco-safety of Monensin

Monensin is an ionophore used to increase feed conversion efficiency and to treat coccidiosis. Cattle are given about 200 mg per animal per day, though they can be given more as they increase in size and with increased feed intake. Monensin can be found in the cattle's waste and is the primary route by which it reaches the environment. Based on dosing studies, typical doses will yield about 3.3 ppm of monensin and metabolites in the cattle feces. Half to 60 percent of monensin is metabolized prior to excretion into less active compounds. The most abundant metabolite, O-desmethyl monensin (accounting for about 5 percent of the total monensin/residues in feces), has a bioactivity that is 20 times lower than monensin itself. Thus, 3.3 ppm is a realistic worst-case limit for monensin in cattle waste.

The FDA considered a worst-case scenario in which manure containing 3.3 ppm monensin was applied to cropland at a rate of 20 tons per acre.[13] After incorporation into the top 6 inches of soil, the concentration of monensin in the soil will be 66 ppb. Studies showed that half of the monensin in soil is degraded in 7.3-7.5 days. Thus, after one month, there would be approximately 4 ppb of monensin in the soil.

If all the monensin in the applied cattle manure (66 ppb) were dissolved in the water from a two inch rainfall event, the water would contain 291 ppb of monensin. Yet monensin binds to moderately textured soils, with research showing that at most 10.8 percent of the monensin in the soil would be in the runoff water. At 66 ppb, this would make the runoff water concentration at most 7 ppb, assuming that the water and soil remained in contact long enough and no new soil was encountered during runoff.

To estimate worst-case feedlot runoff, the FDA considered a scenario in which the soil in the feedlot contained the same concentration of monensin as manure, 3.3 ppm. If 10.8 percent is available for runoff, the highest concentration would be 360 ppb, with actual levels depending on the amount of dilution, soil binding, and degradation. The half-life of monensin in water is 44 days. However, this concentration would be significantly diluted with runoff from surrounding land areas and fields (where the worst-case runoff estimate was 7 ppb) and would not be expected to persist.

Compare these levels with data from the ecotoxicology studies. The highest field soil concentrations were estimated to be 66 ppb and maximum field runoff concentrations no more than 7 ppb. But no effects were seen in earthworms exposed for two weeks in soil containing 10,000 ppb monensin. No effects were seen in bluegill after 96 hours in 3,000 ppb monensin. No effects were seen in rainbow trout after 96 hours in 700 ppb monensin. Daphnia were unaffected after 48 hours exposure to 4,200 ppb monensin.

[13] NADA 095-735 - Rumensin Type A Medicated Article for Cattle - Active Ingredient: Monensin Sodium. Environmental Assessment and Finding of No Significant Impact. August 1989; December 1989. http://www.fda.gov/cvm/FOI/ea_gn.htm

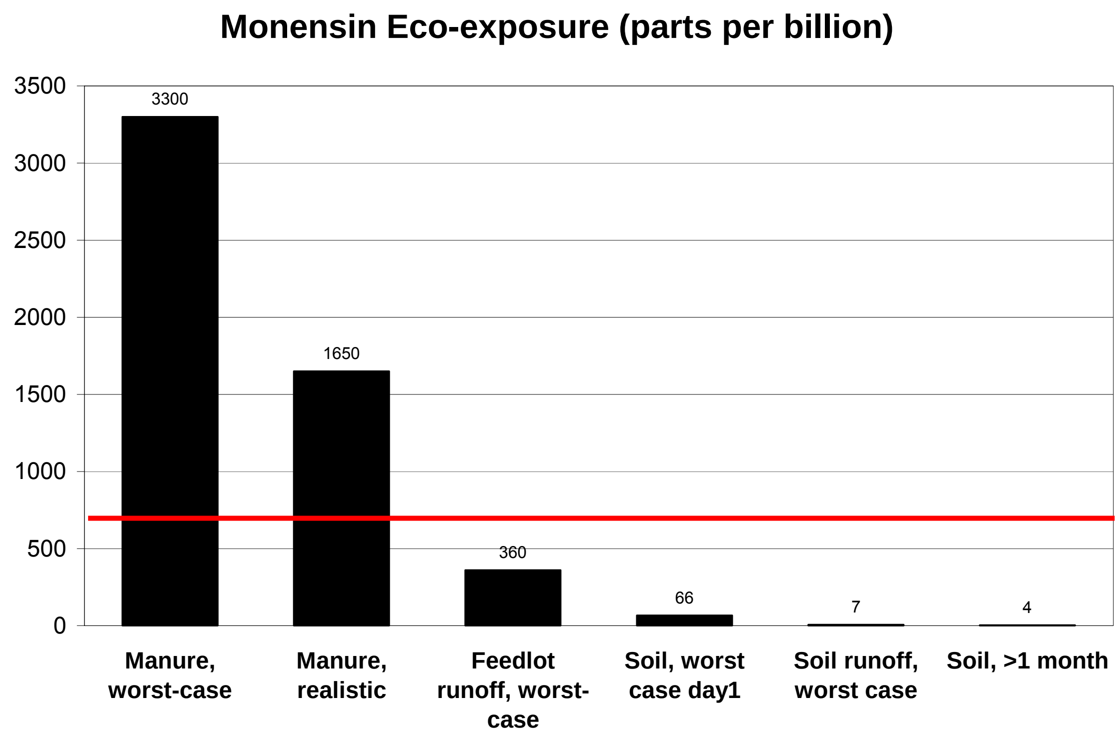

Figure 4. Estimated monensin concentrations in various media. Note: the red line represents the no-effect concentration of monensin for rainbow trout, the most sensitive aquatic species tested.

Additional Water Quality Protections in Feedlots and Animal Feeding Operations

In addition to the assurances of environmental safety that are in-built to the FDA approval process for beef growth enhancement products, beef feedlots and other concentrated 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 beef feedlots there 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 waste and/or wastewater only in the case of catastrophic condition or catastrophic rainfall event, defined as a 100-year, 24-hour rainfall event for facilities built after 2004 or 25-year, 24-hour rainfall event for CAFOs existing prior to 2004.

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 a 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 waste can be applied, including buffer areas around surface waters and no application if ground is frozen, saturated, or during rainfall events. Waste 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 FDA approval process as well as the design and operation of modern beef feedlots. This combination offers strong assurance of minimal ecological impact from their use.

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 municipal waste water treatment facilities is large, is sent directly into surface waters, and includes both natural human hormones as well as supplemental hormones from birth control pills and hormone replacement therapies. Thus, these situations are very different from and not directly comparable to the runoff from cattle feedlots and fields where cattle waste is applied 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 (10-20% of samples).[14] However, their analysis was not based on validated assays (tests) and the accuracy and reliability of these methods remains an open question. Subsequent analysis indicates that there may be many confounders to these data and assays.[15]

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 these sampling site's lack of downstream proximity to a human wastewater treatment works or other expected source. One group of scientists subsequently suggested that 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).

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 not impacted by runoff from cattle production.[16] They reported finding differences in the ratios of various hormones in minnows from the upstream and downstream sites. However, they

[14] 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.

[15] 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.

[16] 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.

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 hormone receptor and the sensitive luciferase "reporter" 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).[17] Indeed, at times the undiluted feedlot drain water registered hormonal activity. However, 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.

[17] 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 of 2006, the United Nations Food and Agriculture Organization (FAO) released a widely-cited report examining this issue, ominously titled "Livestock's Long Shadow."[18] According to the FAO's estimates, livestock are responsible for 18 percent of humanity's carbon dioxide-equivalent greenhouse gas emissions, or more than transportation as a single sector of the economy.

The FAO highlighted that it wasn't just respiration of CO2 and exhalation/flatulence of methane that contribute to possible climate change forcing, but that land-use changes and energy used to produce fertilizers also contribute. Specifically, according to the UN FAO, poultry and livestock are responsible for 9 percent of all human-sourced CO2 emissions, 37 percent of methane emissions, and 65 percent of nitrous oxide emissions.

Any assessment of the environmental impact of beef production systems and technologies must therefore account for these 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 hormones versus pasture- or grass-based finishing. Both systems have their respective advantages and disadvantages. But the two have different environmental impacts, in terms of land used and emissions of green house gases per pound of beef produced. Beef produced in feedlots with the help of growth enhancing hormones requires significantly less total land (including feed crops) and creates substantially fewer greenhouse gasses in the process.

To get a handle on the relative magnitude of differences in resource and environmental costs of the two production approaches, we relied upon a model created by a group at Iowa State University to compare the profitability of various niche beef production methods.[19] This economic model was funded by the Leopold Center for Sustainable Agriculture at ISU in order to help farmers considering transitioning to alternative beef production methods such as organic and natural.

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

---

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

[19] 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

"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 must be stressed that 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 303-329 days before slaughter, whereas most cattle spend no more than 220-240 days in a feedlot and usually only about 150 days. According to July, 2007 Cattle Fax, the average U.S. beef animal spends 150 days on feed.[20] This means that beef cattle typically spend 20-50% less time in a feedlot than assumed in the ISU model.

If these shorter, real-world finishing periods were compared, the environmental benefits of feedlot systems would be even more striking compared to grass-based finishing. Nonetheless, the ISU comparison serves as a useful baseline comparison that, while favoring the grass-fed system, still demonstrates the benefits of finishing cattle in feedlots using growth promoting pharmaceuticals.

Environmental Cost Comparison

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

The modeled grass-fed 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 slaughter. The grain fed model system assumes 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.

Accordingly, a grass-based finishing operation with 100-cow herd requires 660 acres of pasture and hay, whereas the grain-fed farm requires 365 acres of pasture, hay, and corn. The model assumes the farms sell 77 feeders (48 steers and 29 heifers) at the end of the process, retaining 20 replacement heifers for the next cycle, and assuming a 3 percent pre-weaning death loss.

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

Table 2.	Organic grass-fed	Natural grain-fed	Conventional grain-fed
Starting weight, lbs	425	475	475

[20] Cattle Marketing Information Service, Inc. Summary of Activity. Cattle Fax Update, Issue 28, volume XXXIX, July 13, 2007.

Days on feed	366	329	303
Post weaning Ave Daily Gain	**1.65**	**2.36**	**3.06**
Feed:Gain, 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 affect the amount of resources used per pound of beef produced. The biggest factors in resource use efficiency are:

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

To calculate land costs per pound of beef in the three model farms, we multiply the total farm acreage and the number of days on feed. We then divide this number by the total pounds of finished beef produced.

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.

The average grass-fed organic cow yielded a carcass weight of 623 pounds. Multiplied by the 77 animals sold for slaughter, the total beef yield was 47,971 lbs. This yields a land use per pound of beef produced:

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

The land costs per pound of beef for the three finishing systems are given in Figure 5 below.

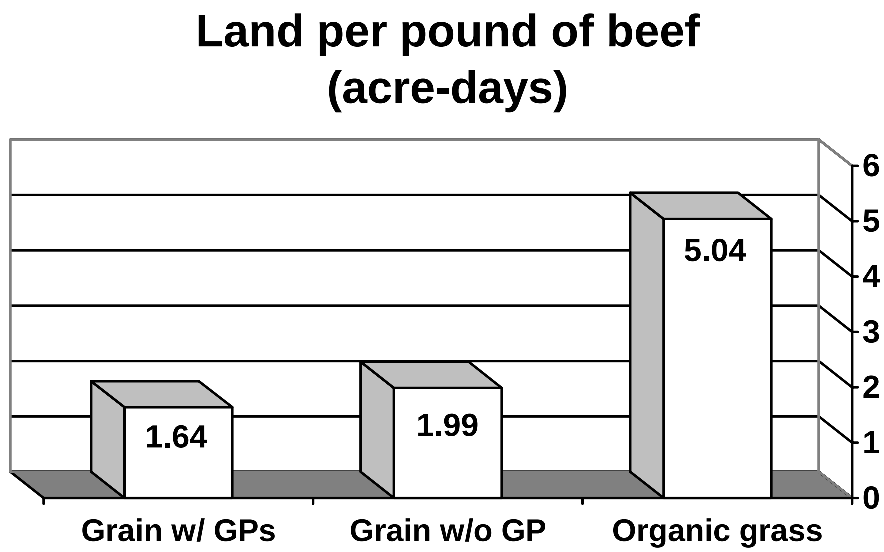

Figure 5. Land area needed to produce a pound of beef during finishing phase.

Thus, grain-finished beef produced using growth promoting implants and ionophores is 3 times more land efficient than organic grass-fed beef, requiring only one-third of the land per pound of beef in the ISU model. When compared to natural grain-fed finishing (i.e. grain-fed in feedlots but without hormones and ionophores), the conventional method is 20 percent more land efficient. Thus, growth promoting implants and ionophores conserve considerable land for other purposes by allowing a substantial increase in land use efficiency over grain-based feeding 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 to +38 percent, with an average increase of nearly 14 percent. Conversely, the individual trial effects of growth promoting implants on feed to gain (FTG) range from +7.7 down to nearly 23 percent, with an average decrease of 8.8 percent.[21] 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

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

---

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

The land use efficiencies of these three systems (from Figure 5) can be translated into a Habitat Conservation Quotient (HCQ, see Figure 6). For example, each acre of land devoted to grain-finishing beef (both feedlot acres and land needed to grow the feed) saves 1.5 acres of land that would be needed to produce the same amount of beef in an organic grass-finished system. Thus, the grain-finishing system earns a HCQ of 1.5.

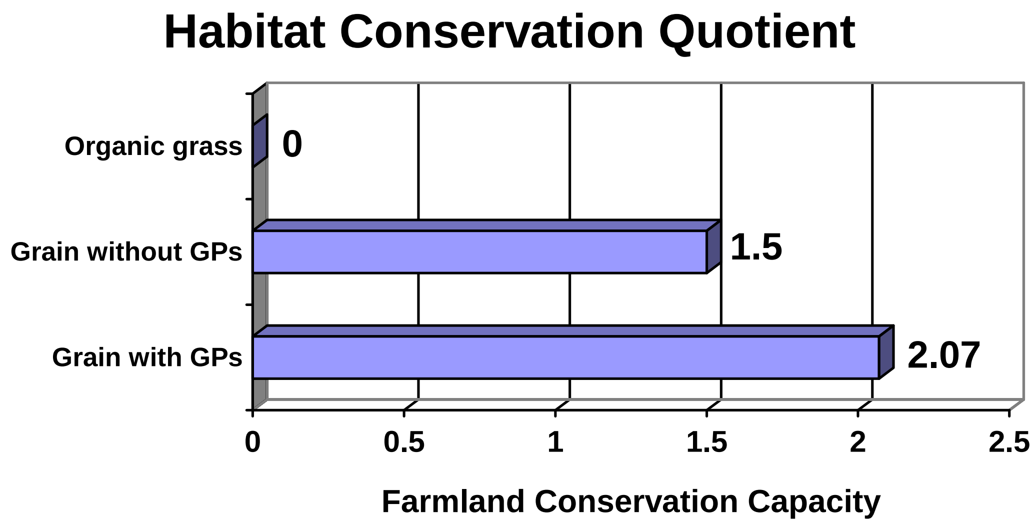

Figure 6. Relative land/habitat conservation capacity based on the amount of land needed to produce a pound of beef from Figure 5.

Grass finishing of beef is an efficient use of poorer-quality farmland less suited for growing feed crops. There are several regions on the globe where grass production is arguably the best, most environmentally sensitive use of farmland. In such places, grass-based beef production is a "good" use of such farmland, especially given the growing consumer demand for grass-based beef. However, in areas with land suitable for growing feed crops, grain finishing is the "better," more resource-efficient use of the land.

Finally, grain finishing with the aid of growth promoting implants and ionophores represents arguably the "best", most efficient use of the farmland resource. Producing beef in this manner scores a HCQ of 2.07, meaning that each acre of land devoted to producing beef in feedlots with the aid of growth promotant hormones and ionophores conserves 2.07 acres of land that would otherwise need to be farmed if the beef was produced under organic grass management. (Remember that these are likely an *under*estimate of the habitat/land conservation capacity of grain finishing with growth promoting pharmaceuticals because they are based on the ISU economic model that assumes cattle spend twice as long in feedlots than they actually spend)

Given:
- the growing world population;
- the increased per capita demand for beef and other high-quality animal proteins;

- the severely limited land area on which to produce food, feed, and fiber for humanity (currently estimated 40% of total world land area);
- increased pressures to conserve natural and biodiverse habitats for nature

It is imperative that we use each and every farmland acre to its best and most productive use. To that end, we should view each system in terms of its overall land use efficiency. While utilizing grass and grazing lands for beef production converts a human inedible resource into a nutritious edible protein, grain feeding utilizes cropland in a fundamentally land-conserving manner by allowing more land to be devoted to other human uses or by allowing humanity to conserve wildlife habitats that would otherwise be converted to farmlands.

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. All livestock production results 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, and nitrous oxides (NOx) production from farmland and manure management.

According to the U.S. Environmental Protection Agency, U.S. agriculture accounts for 7 percent of total U.S. CO_2-equivalent greenhouse gas emissions in 2005.[22] Of this 7 percent, beef production accounted for roughly one-third, or 2% of total U.S. emissions. Roughly half of beef's share of agricultural emissions is from methane emissions related to manure and enteric fermentation (~1% of U.S. total) and half from nitrous oxides from crop and grasslands (~1% of U.S. total).

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 UN FAO, however, beef and buffalo emit nearly 2 billion tons of CO_2 annually via

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

respiration, and each cow emits roughly 3.8 lbs of CO_2/year by respiration for each pound of live weight.[23] 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 can 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 3. Respiration CO_2	**Organic Grass-fed**	**Natural Grain-fed**	**Conventional Grain-fed**
Average live weight per animal, lbs	727	863	938
per animal 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 finished beef, lbs	**5.77**	**4.9**	**4.39**

As shown in Table 3, 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 hormones and ionophores 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.

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-fed 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. The 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, 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-fed cattle 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% 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

[23] UN FAO. 2006. op cit page 96, Table 3.6.

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.[24]

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-fed beef, 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 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-fed cattle in feedlots will produce only 57.2 lbs.[25]

Note: Monensin increases the efficiency of fermentation in the rumen, which consequently lowers methane emissions, as well as manure excretion – both of which will reduce overall methane production even further than grain feeding and the use of other growth promotants. According to recent research, use of monensin reduced methane emissions by nearly 10 percent in dairy cows.[26] Other research suggests monensin may reduce methane emissions in beef cattle by as much as 25 percent.[27] These effects were not considered in this analysis, but their positive environmental impact should be recognized.

[24] 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% of total CO_2 equivalent emissions, so this omission does not substantially impact the results.

[25] UN 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 1kilogram.

[26] Odongo NE, Bagg R, Vessie G, Dick P, Or-Rashid MM, Hook SE, Gray JT, Kebreab E, France J, McBride BW. 2007. Long-term effects of feeding monensin on methane production in lactating dairy cows. J. Dairy Sci 90:1781-1788.

[27] Tedeschi LO, Fox DG, Tylutki TP. 2003. Potential environmental benefits of ionophores in ruminant diets. J Environ Qual 32:1591-1602.

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-fed cattle and 20.9 lbs per head per year for grain-fed cattle.[28] 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 4. Methane emissions	Grass-fed	Grain-fed
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 values 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-fed" and 366 days for organic grass-fed) and divide this by the total pounds of beef produced. (See Table 6)

Table 5. Estimated CO2-equivalent emissions	Grazing	"Natural" feedlot	Conventional feedlot
CO_2 equivalent emissions per head at slaughter, 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.

Table 6. CO_2 equivalent emissions per pound of beef	Grazing	"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 (excluding NOx)	**11.16**	**7.94**	**6.93**

[28] UN 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.

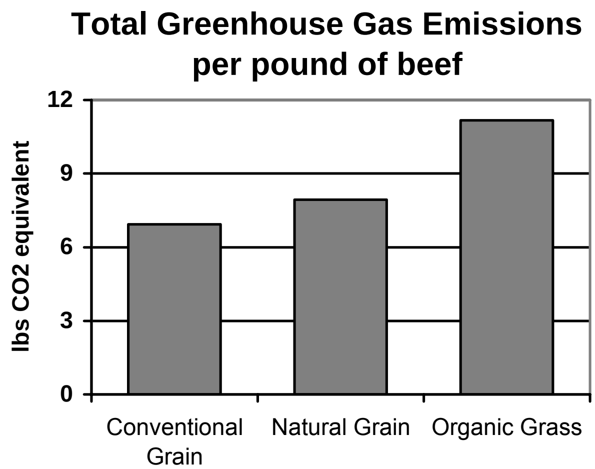

Figure 7. Greenhouse gas emissions per pound (excluding NO_x)

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 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.[29] Their studies have shown that of total CO_2-equivalent GHG emissions from beef production, 48% are from N_2O (all sources – animal manure, crop N-fertilization, legume and waste using IPCC 2001 factors), 41% are from methane (40% enteric, 1% manure), and 11% are from fuel CO_2 (both fuel and fertilizer). The cow-calf phase of production emits 75% of beef system GHGs, with emissions of just over 16 kg CO_2-equivalent GHG per kg of product. This is about twice that of the stocker phase, and nearly three-fold 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 they modeled, 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

[29] 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

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 grow animals 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 benefits. 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.