Ecological Footprint of a Cattle Feedyard

How is it Affected by Water Use?

The Dream

Motivation

- "Sustainability" is ultimately both an *ecological* and an *economic* question
- Water resources play a key role in both the *ecology* and the *economy* of the High Plains
- Linking *ecology* and the *economy* has always been a vexing challenge…
- …How does one trade environmental benefits in one medium (e. g., air) for benefits in another (e. g., water) *using a common basis of measure?*

Where We're Going

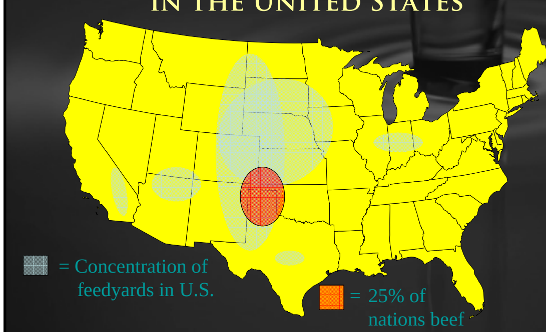
- What is the water-use intensity of the feedyard industry?
- What the Sam Hill are "ecological footprints" and "embedded energy?"
- What are some benchmark values for a typical cattle feedyard?

Water-Use Intensity of Cattle Feedyards

Special Thanks to:

Drs. John Sweeten and David Parker

The Fed Cattle Industry in the United States



The Fed Cattle Industry in the United States

- The trend to fewer, larger feedyards continues
- Nearly 60% of cattle are marketed from about 200 feedyards
- The number of cattle marketed from yards with fewer than 1,000 head has declined to under 3 million
- Average capacity in Texas High Plains: 40,000+

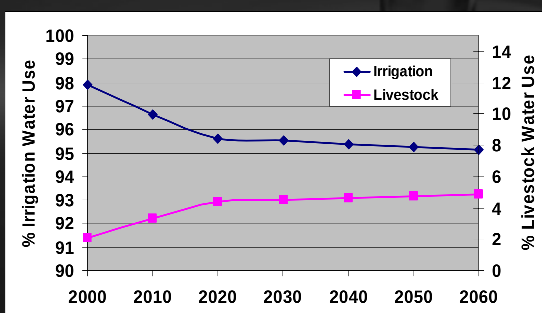
Ogallala Situation (Sweeten, 2006)

- Provides 90%+ of ag water supply
- Surface water over-subscribed
- Irrigation use ~ 90% of total
- Increasing livestock water use by CAFOs – 3-6%
- Depleting aquifer, TX, OK, NM, KS, CO
- Economic competition for water

- Example, gross receipts:
  - Irrigated crops ~ $9 - $25/ac-in
  - Feedlot or dairy ~ $ 3,000/ac-in as drinking water
- Grain (rainwater!) imports from rain-fed states >50%
- *"Long-range strategies needed"*

Irrigation vs. Livestock

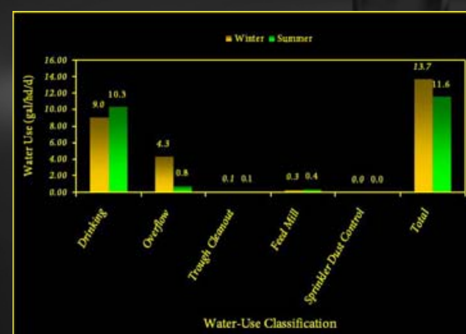
(expressed as % of gross agricultural water use)



Texas Panhandle Regional Water Planning Group, 2003.

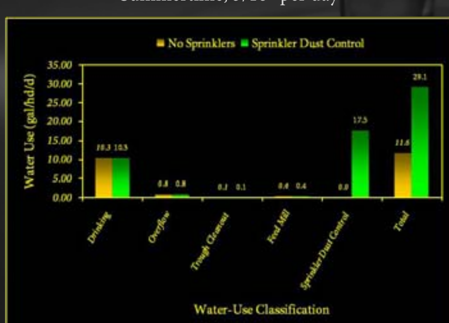
Seasonal Water Use

(excludes dust control; adapted from Parker et al., 2000)



Influence of Sprinkler Dust Control on Gross Water Use

Summertime, 3/16" per day



Reducing Feedyard Water Use

- *More efficient* water troughs
- *Electric* tank heaters for existing troughs
- Repair water trough leaks at threaded standpipe
- *Collect* & *reuse* overflow water for :
  - Water treatment/reuse system—*filtration/chlorination*
  - *Irrigation*, with or without effluent blend
  - Dust control, pens and/or roads
  - Feedmill

The "Rebound Effect"
(Is *more efficient* necessarily *better*?)

- Decline of the High Plains Aquifer has accelerated despite irrigation regimes that approach or exceed 95% application efficiency (Marek, 2005; Allen, 2006)
- American farms have doubled their energy efficiency since 1978…still, due to more advanced processing, U.S. agriculture uses at least ten calories of fossil energy for every calorie of food energy produced (Miranowski, 2004; [acb] Lovins, 2005)
- My new 3GHz PC still takes 4 minutes to boot up
- *We plow efficiency savings back into the enterprise to maximize profit instead of reducing net inputs*

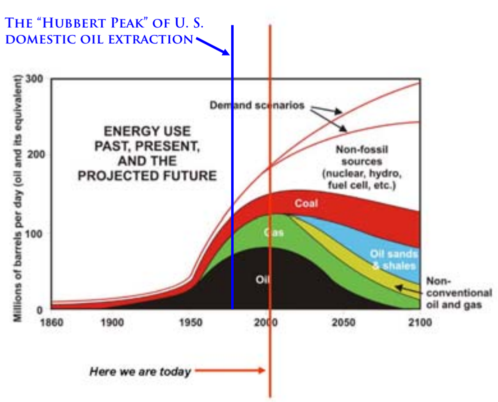
As we approach the limits of our easy access to energy, the defining economic currency will be dominated by availability of energy units rather than by an artificial currency, be that gold or dollars.

Paul Weisz
2004

Reducing Feedyard Water Use

- *More efficient* water troughs (CE)
- *Electric* tank heaters for existing troughs (EE)
- *Repair* water trough leaks at threaded standpipe (LE)
- *Collect* & *reuse* overflow water for :
  - Water treatment/reuse system—*filtration/chlorination (EE)*
  - *Irrigation*, with or without effluent blend (EE)
  - etc., etc.

Ecological Footprints and Embedded Energy

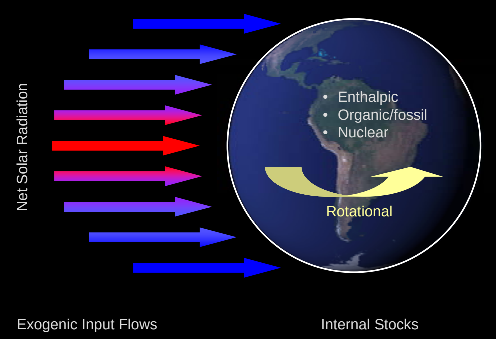


Adapted from Rees (2003)

Some General Truisms

- Domestic extraction of [ ] will cease when one barrel of it is required to extract one barrel of it from its most accessible reservoir
- Extraction of fossil fuels – among other things it accomplishes, and whatever the ecological implications might be – moves energy and carbon from the *lithosphere* to the *ecosphere*

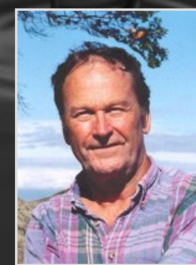
Sources of Primary Energy in the Ecosphere



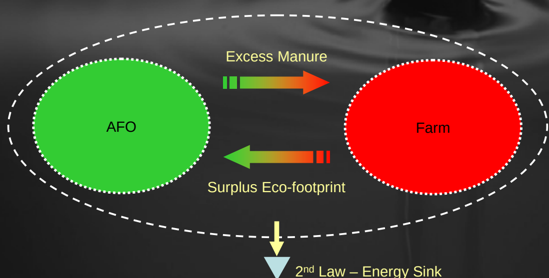
Ecological Footprint
(W. Rees et al.)

The *per capita* area of ecologically productive land and/or ocean needed to sustain an ecosystem continuously by:

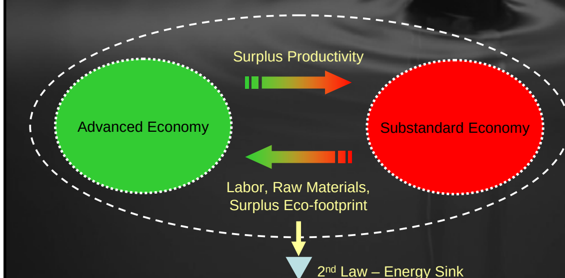
- Providing all of the material and energy resources that it requires; *and*
- Safely assimilating all of the wastes that it generates
- ***Does it exceed the EP area available?***



Trade Couples Ecosystems



Globalization Couples Distant Ecosystems



Why Energy, and Not Matter?

- ✓ Both matter and energy are conserved
- × There is no "mass sink" equivalent to the inevitable increase in system entropy
- ✓ We can conceivably recycle matter *ad infinitum*…
- × …given an inexhaustible source of available energy to do so
- × Irreversible processes are the norm: energy is conserved, but *its ability to do work* is not!

Ecological Footprint

- Average daily insolation is roughly 3.09E+10 joules per square meter (3.09E+10 J/m^2)
- The closer to the Equator, the greater the daily insolation
- "Ecologically productive" land area and ocean absorb the solar energy and convert it to higher-order, organic-energy stocks (e. g., CHONS as biomass), wind, precipitation etc.
- ***EF converts incident solar energy to incremental ecological services***

Emergy: Embedded Energy
(H. T. Odum et al.)

The available energy having an arbitrary reference quality (e. g., solar radiation) previously required – directly and indirectly – to make a product or service

- Normalizes available energy to common units ("emjoules")
- Accounts for transformations among energy types that differ in their ability to do useful work

One Key Assumption

- I assume that we can design/engineer systems to accomplish just about anything worthwhile to an arbitrarily high degree of reliability

Example #1

- Recommendation: *Build an advanced weapon to bring the war to a rapid close and save American lives*
- Application: *^{235}U enrichment at K-25/Y-12 in Oak Ridge, TN, 1942-1945*
- Marginal Energy Costs:
  - *Mechanical energy to transport, pulverize ore; compress UF_6*
  - *Thermal energy to accelerate isotope diffusion*
  - *Electromagnetic energy to enhance isotope separation*
  - *Implication: From an ecological perspective, "Fat Man" and "Little Boy" were highly concentrated fossil-fuel bombs*

Example #2

- Recommendation: *Increase N&P use efficiency by increasing feed digestibility and nutrient availability*
- Application: *Steam-flake grain*
- Marginal Energy Costs:
  - *Thermal energy to generate steam and pressure*
  - *Fluid energy to pump water, transport grain*
  - *Mechanical energy to drive rollers*

Example #3

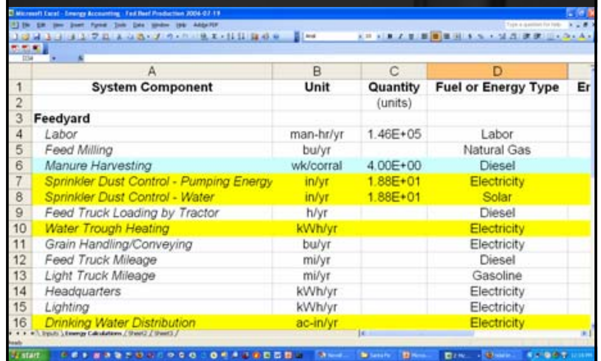
- Recommendation: *Increase break-even distance for hauling manure profitably as a phosphorus source, and reduce weed and pathogen viability and pesticide use*
- Application: *On-farm composting*
- Marginal Energy Costs:
  - *Mechanical energy to handle manure, turn compost*
  - *Biological energy to increase pile temperature, evaporate water, oxidize organic matter to CO_2, NH_3 and trace gases*
  - *You get the idea by now*

Applying Energy-Based Currencies to Feedyard Water Use

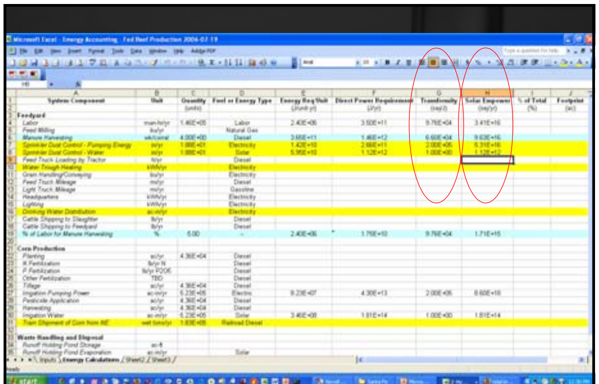
Implications and Benchmark Values

Odum Studied Texas Agriculture (1987)

- Farm and ranch marketing were ~4% of GSP
- Emergy consumption was ~13% of total state emergy consumption
- Odum interpreted this as suggesting Texas agriculture's contribution to the state economy (measured as equivalent solar energy) was 4.5 times the value Texas was reaping in gross receipts



	A System Component	B Unit	C Quantity (units)	D Fuel or Energy Type
3	**Feedyard**			
4	*Labor*	man-hr/yr	1.46E+05	Labor
5	*Feed Milling*	bu/yr		Natural Gas
6	*Manure Harvesting*	wk/corral	4.00E+00	Diesel
7	*Sprinkler Dust Control - Pumping Energy*	in/yr	1.88E+01	Electricity
8	*Sprinkler Dust Control - Water*	in/yr	1.88E+01	Solar
9	*Feed Truck Loading by Tractor*	h/yr		Diesel
10	*Water Trough Heating*	kWh/yr		Electricity
11	*Grain Handling/Conveying*	bu/yr		Electricity
12	*Feed Truck Mileage*	mi/yr		Diesel
13	*Light Truck Mileage*	mi/yr		Gasoline
14	*Headquarters*	kWh/yr		Electricity
15	*Lighting*	kWh/yr		Electricity
16	*Drinking Water Distribution*	ac-in/yr		Electricity



Example #4

- Recommendation: *Take advantage of sparse populations by importing water from other places to perpetuate the feedyard industry in the Texas Panhandle*
- Application: *Coastal desalination plants and pipelines to the High Plains*
- Marginal Energy Costs:
  - *Electrical energy to drive reverse osmosis systems, pump desalinated seawater, etc., etc.*
  - *Again, we're trying to accelerate what the ecosphere already does for us using solar energy*

Emergy of Feedyard Water Use

- Groundwater (GW) used for sprinkler dust control represents 50-80% more emergy than cattle drinking water (solar distillation basis)
- ***Pumping*** GW for sprinkler dust control represents 47,000 times as much emergy than the emergy content of the water itself
- Manure harvesting consumes ~85% more emergy (in labor and diesel) than sprinkler dust control
- Corn grown locally to satisfy a feedyard's grain requirements consumes 100 times the emergy *in irrigation alone* than the water pumped for cattle drinking

A Reminder

- We can design/engineer systems to accomplish ecological sustainability to an arbitrary degree of reliability
- But *can we afford it* at current levels of energy use?
- What about at *future* levels?

A Sustainability Conjecture

No terrestrial ecosystem of can be considered sustainable if it must be subsidized indefinitely by non-renewable energy

The Black-Gold Standard: A Working Definition

Given a certain enterprise, a certain level of ecological stress or a certain product, assuming no energy were available from non-renewable sources, how much equivalent solar energy (or power) would have to be set aside and dedicated to sustain that enterprise, manufacture that product or mitigate that stress?

Future Directions

- One need not accept all of Rees' and Odum's conclusions in order to adopt their analytical perspectives
- We are seeing today a rapid lurch toward a more plausible linkage between energy scarcity and market prices
- Water resources play a key role in the Green Revolution, but Hubbert's Peak looms
- Can we use embedded-energy analysis to evaluate the sustainability of our water-resource technologies?
- Net emergy would be a good basis for comparing sorghum diets to corn diets

In the long run, we're all dead.

John Maynard Keynes
1923