The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

The Connection Between Food Supply and Energy: What Is the Role of Oil Price?

Posted by Prof. Goose on October 23, 2007 - 10:00am
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This is a guest post by Glenn Morton, a geophysicist in the oil industry. For Kerr-McGee Oil and Gas Corp., Glenn served as Geophysical Mgr Gulf of Mexico, Geophysical Mgr for the North Sea, Dir. of Technology and as Exploration Director of China. Currently he is an independent consulting geophysicist, and you might know him as seismobob.

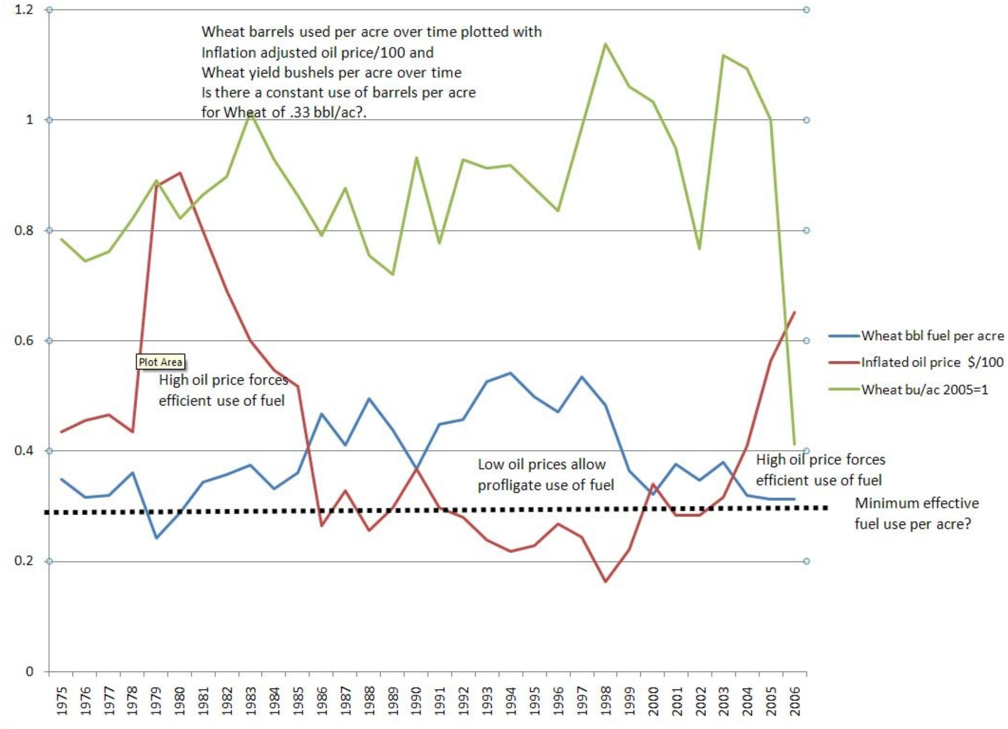
I became fascinated with the connection between our food supply and energy when I first learned of the problems that North Korea was having feeding itself. (see here). This data showed me something amazing about modern society, we don't live in the information age, we don't live in the industrial age, we live in the *agricultural* age. Without food, we have no industry or information. Unfortunately many don't understand this. Nor do they understand that today the modern farming system is merely a means to turn petroleum into food, via mechanized planting and harvesting, and the use of petroleum based insecticides and fertilizers which consume huge amounts of energy in their manufacture. According to Wikipedia, who gets it from Science, 1% of the world's energy goes into the manufacture of chemical fertilizer (here).

There has recently been a claim that in the post-peak oil world, life will go on pretty much as normal. For a while, as the world squeezes inefficiencies out of the economic system and fuel switching occurs, this is true. But one can not seriously believe that the world economy is infinitely elastic with regards to energy. With regard to the agricultural system, there is data which shows the limits to this inelasticity and these limits are due to the laws of physics.

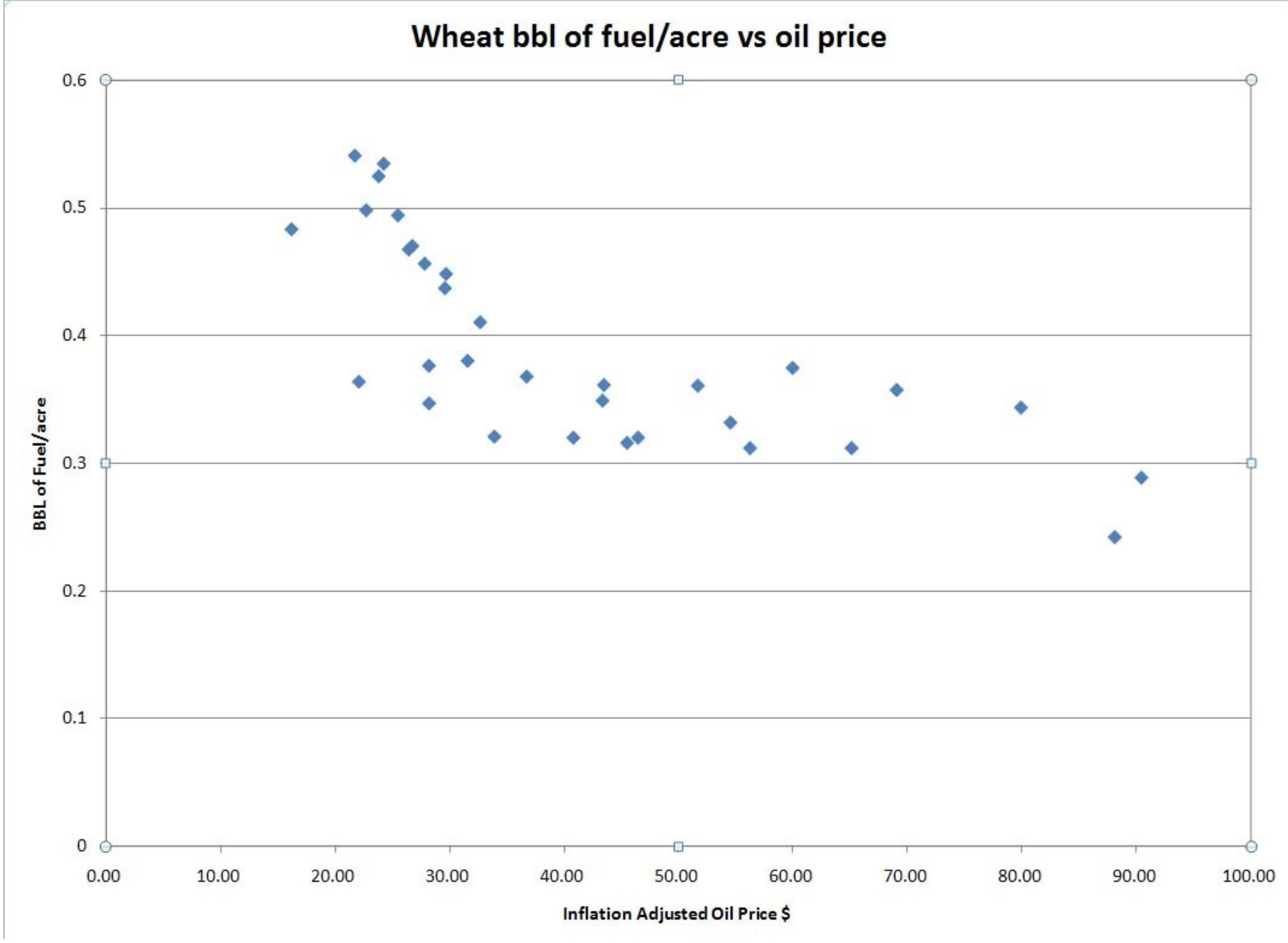
The USDA provides information on the economics of farming. The data comes in the form of dollars spent on various items. I will focus on the dollars spent for fuel, chemical sprays and fertilizer. These three items are directly related to petroleum, and using the cost of the day and the price of oil of the day, one can convert these numbers into barrels of oil spent. For instance, in 1975 wheat farmers spent an average of $11.44 per acre on fertilizer. As noted above, fertilizer is an energy intensive product and its value is largely determined by the amount of energy used. Since the price of oil in 1975 averaged $11.53/bbl, this means that the wheat farmers spent .99 bbl/acre on fertilizer. The farmer spent only $1.19 on chemical sprays per acre meaning he spent .1 bbl/ac. Fuel is much more directly (although not perfectly) convertable to barrels. In 1975 farmers spent $4.02/ac. on fuel and lube, which is converted to .35 bbl/ac. With this methodology I studied the energy expenditures on wheat, corn, rice and barley farming.

These four crops are the major food-grains of the world. How the farming community responds to high oil prices is of immense interest to the world community. If, as that author, mentioned above, claims the world will have 25-30% less oil in 2030 with no ill effects, this can only be true if agriculture has the elasticity to handle such a reduction. Sure we can drive less, take buses to work, drive motor scooters etc. This will seriously reduce the demand for energy. But, can we drive a tractor plowing a field 25% less? I don't think so. This is because of the laws of physics. The energy used to move a tractor across a field is Work = force x distance. The distance is constant, and so is the force (or nearly so). The force here is actually the frictional forces the tractor experiences. They must be over come. If there were no friction, then Newton's first law, that a body in motion remains in motion would come into play and a tractor once set moving could continue to move in a straight line. But because the plow against the dirt, the tires against the dirt, the internal friction of the engine all operate to slow the tractor down, there is a minimal energy which must be expended if one expects to plow that field. The question is, can we see that limitation in the data from the USDA?

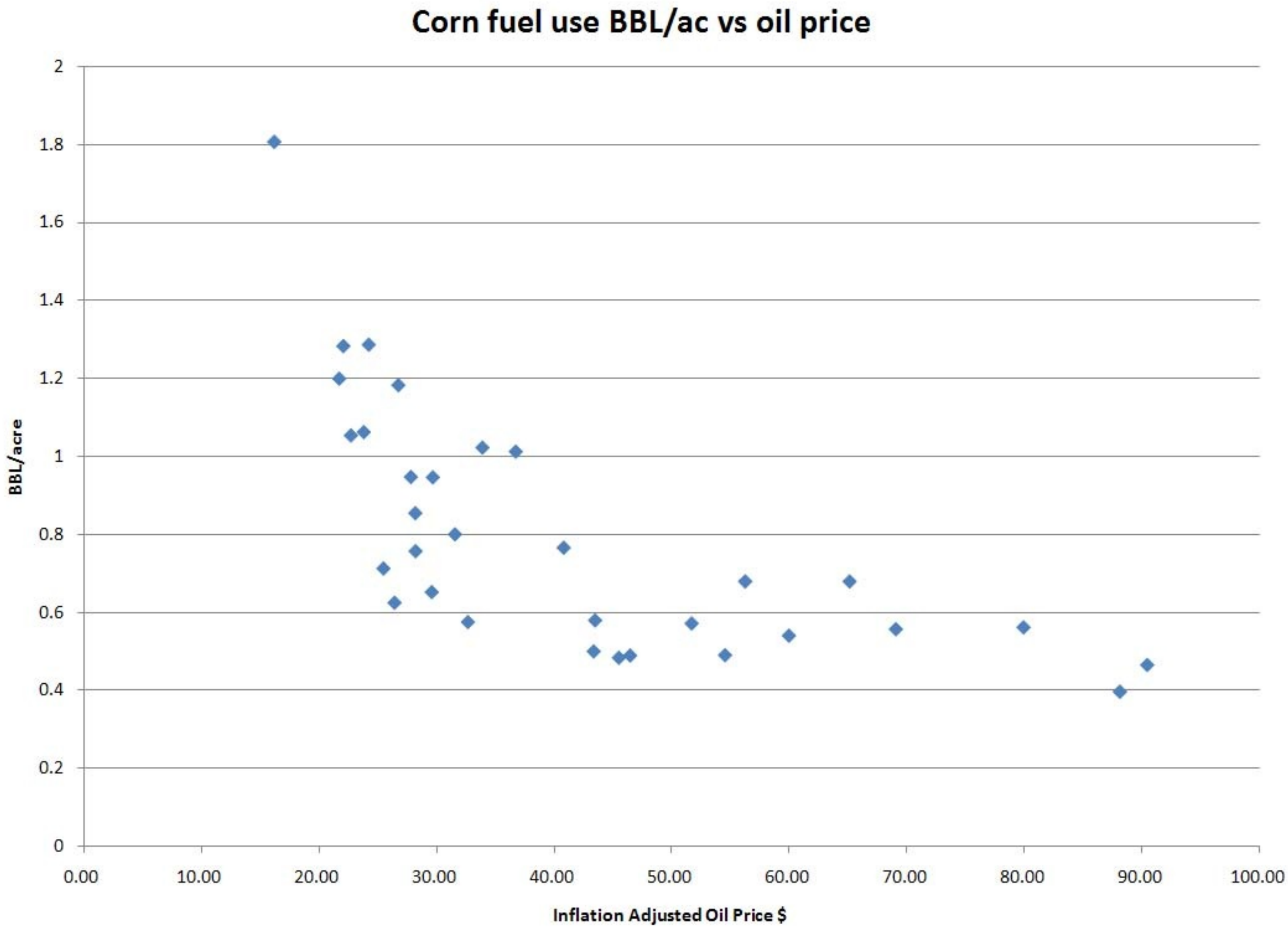
In plotting the oil price, yields and fuel costs of wheat farmers over time, I noticed that there does appear to be a minimum energy expenditure in the data. The inflation adjusted price of oil is scaled to fit onto this graph, and both the uninflated and inflated oil prices come from the 2007 BP Statistical Review of World Energy. One immediately sees that when the price of oil is high, the fuel use drops to approximately .3 bbl/ac.. When the price of oil is low, the fuel use rises. One can find a similar thing for rice, corn and barley.

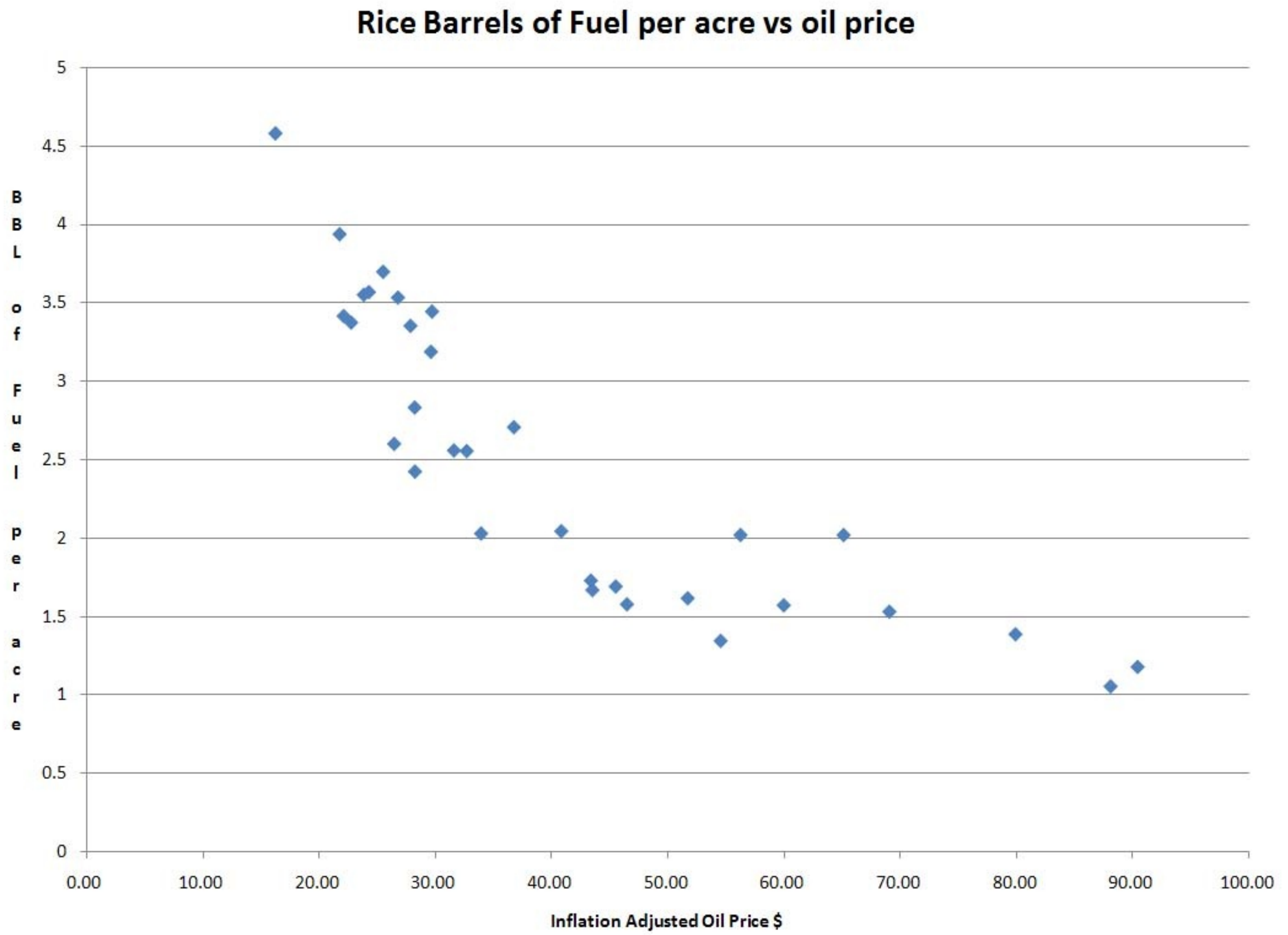


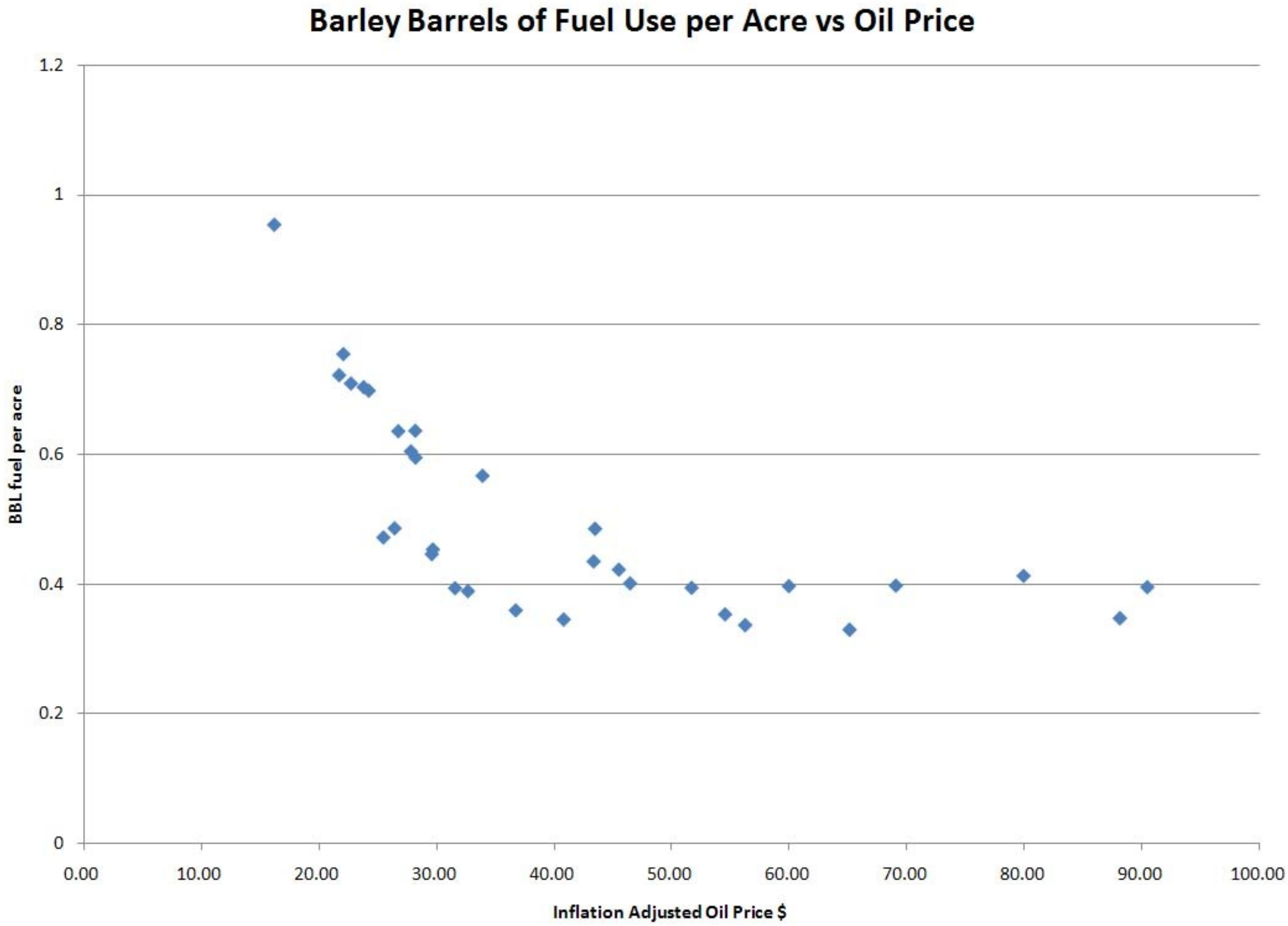
I won't show the same thing set of charts for the other grains (although corns minimum effective fuel use seems to be rising), because one can display the data more effectively in another format. By making fuel use a function of inflation adjusted oil price, one sees the elasticity of fuel use on wheat farms. Below $40/bbl, the use of fuels to drive equipment rapidly rises. Clearly the farmers are having few pangs of guilt about driving any equipment when the prices is below $40. But the behavior is quite different when the price reaches $40/bbl. Fuel use flattens out, as if almost all of the elasticity has been removed from the system. Only at the $90 level is there any evidence of further restrictions in fuel use. I would conclude from this that at $75/bbl, wheat farming has already squeezed out the inefficiencies and given a 20-30% drop in future supplies as is expected, the only way to accommodate this is to not drive as much (although, fertilizer and chemical use will turn out to be more elastic)



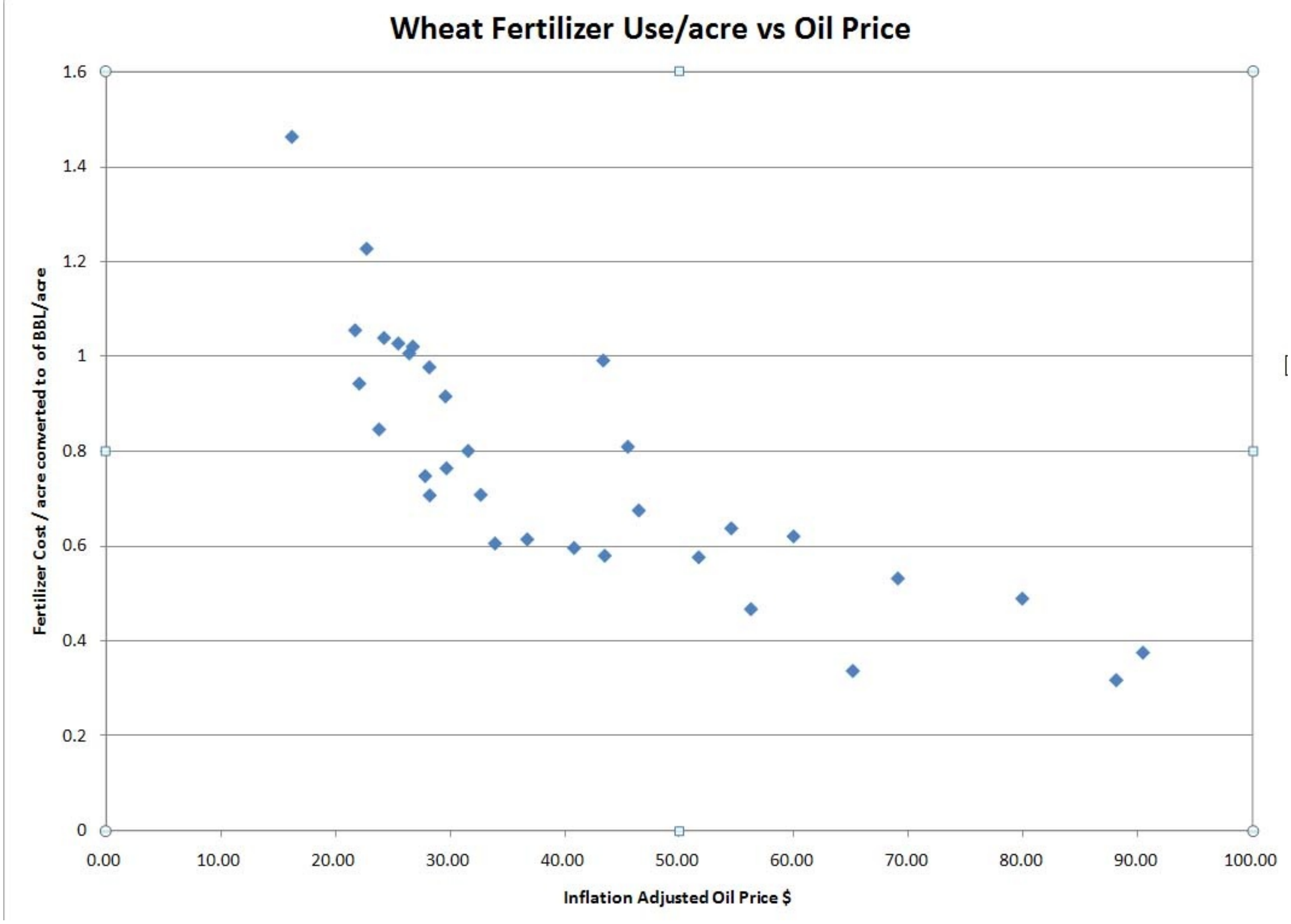
Here is the same for corn, rice and barley

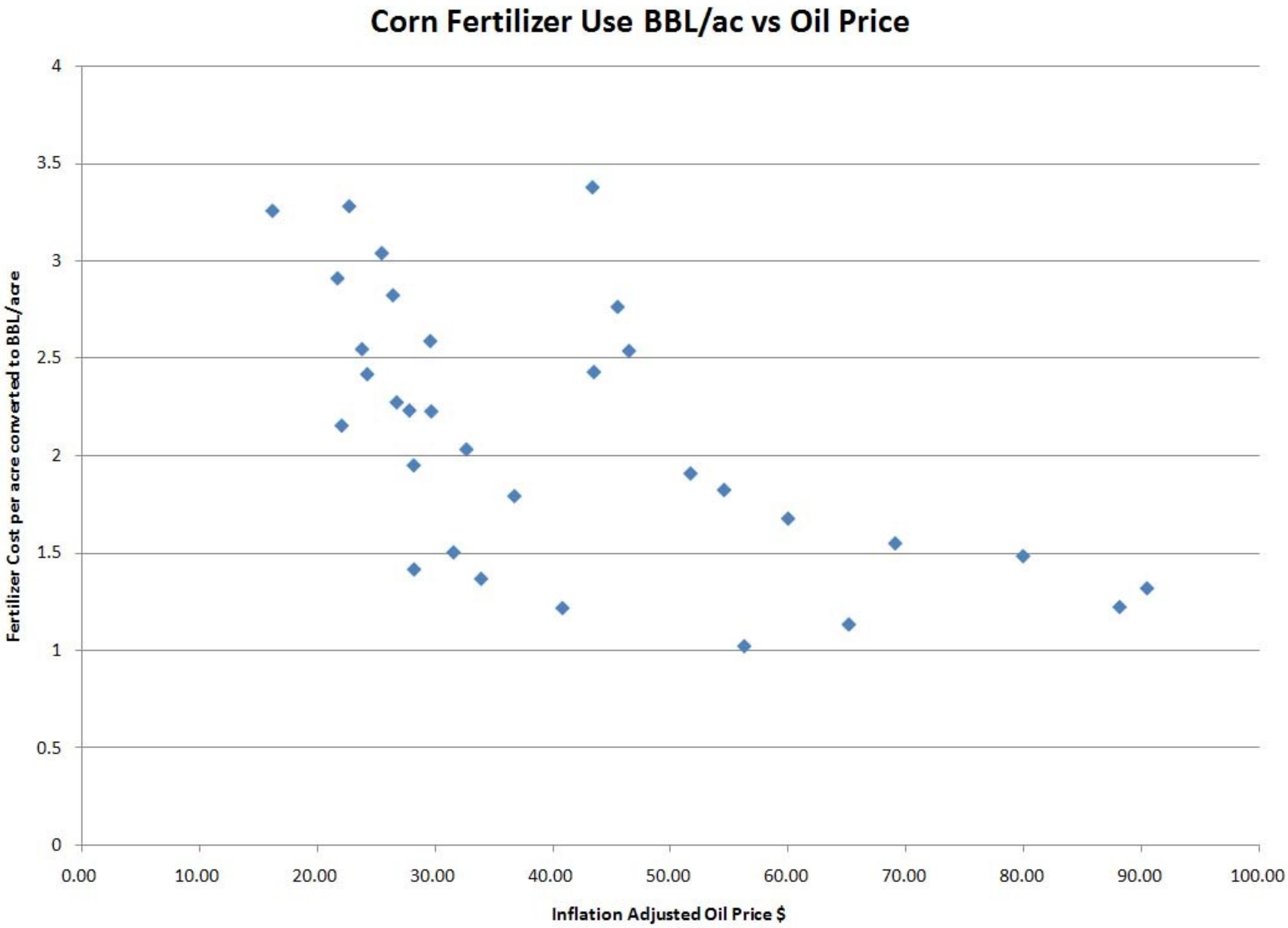

Corn fuel use BBL/ac vs oil price
BBL/acre
Inflation Adjusted Oil Price $
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

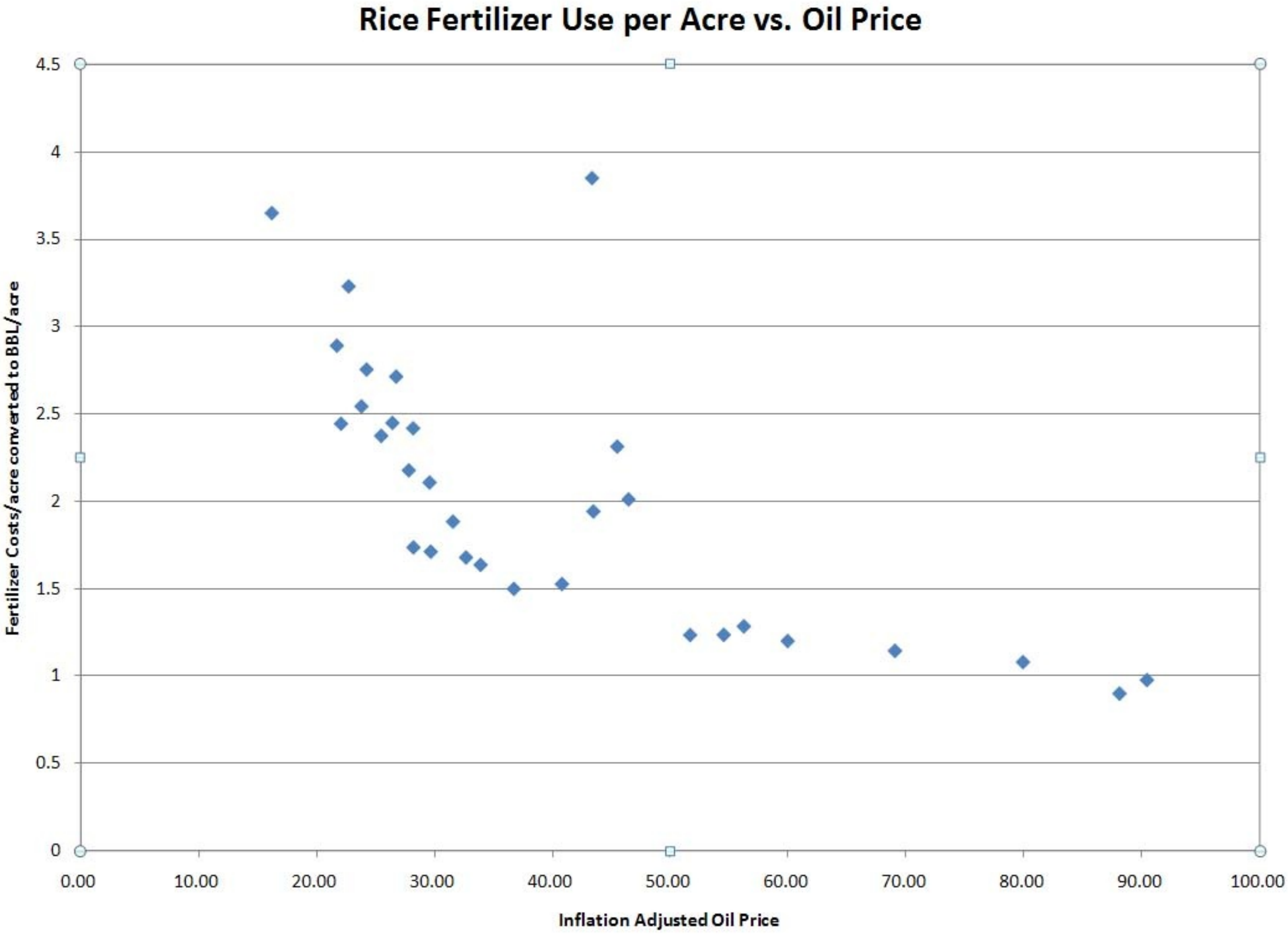

Rice Barrels of Fuel per acre vs oil price
BBL of Fuel per acre
Inflation Adjusted Oil Price $
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

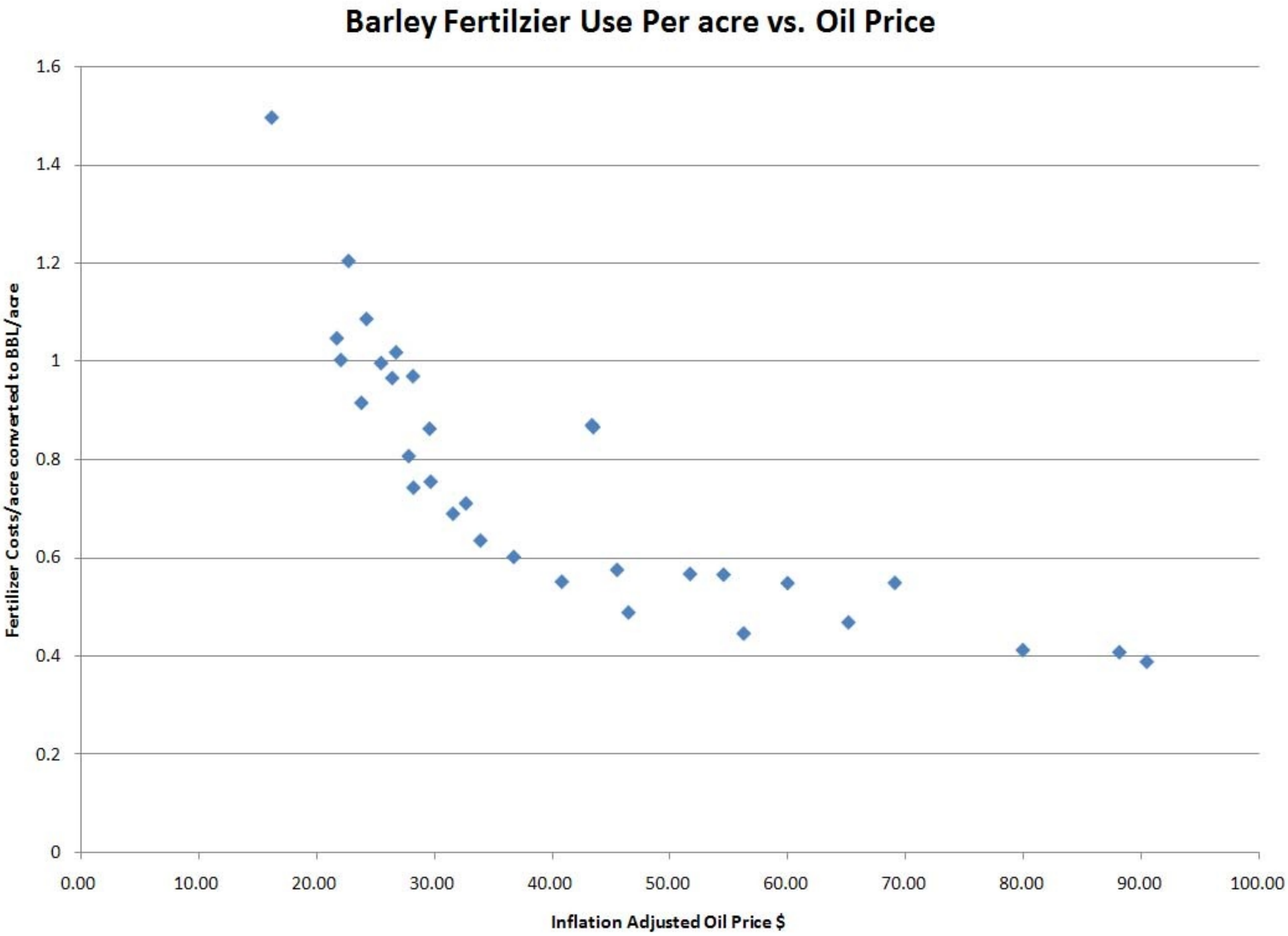


What about fertilizer use?


Wheat Fertilizer Use/acre vs Oil Price
Fertilizer Cost / acre converted to of BBL/acre
Inflation Adjusted Oil Price $
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

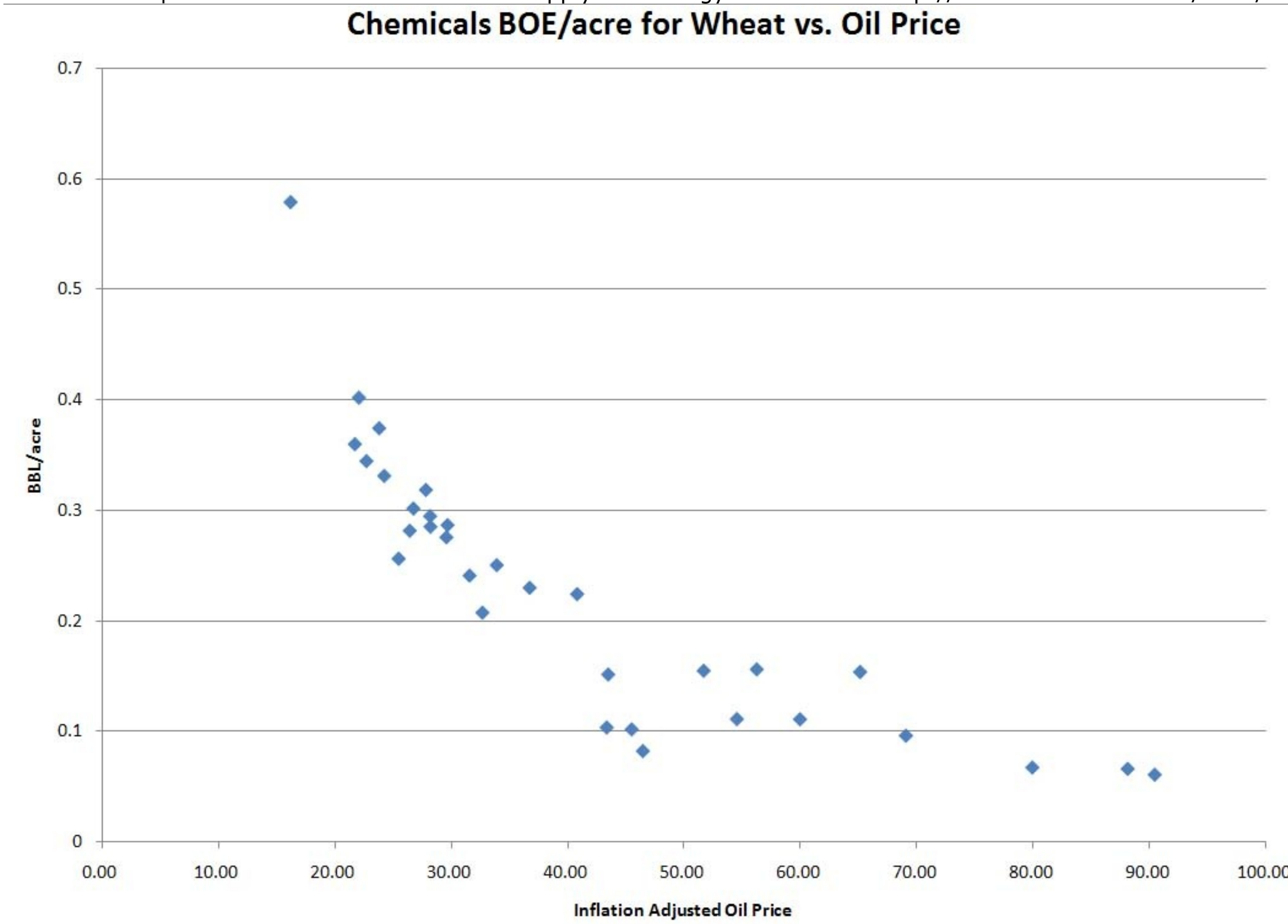

Corn Fertilizer Use BBL/ac vs Oil Price
Fertilizer Cost per acre converted to BBL/acre
Inflation Adjusted Oil Price $
0
0.5
1
1.5
2
2.5
3
3.5
4
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

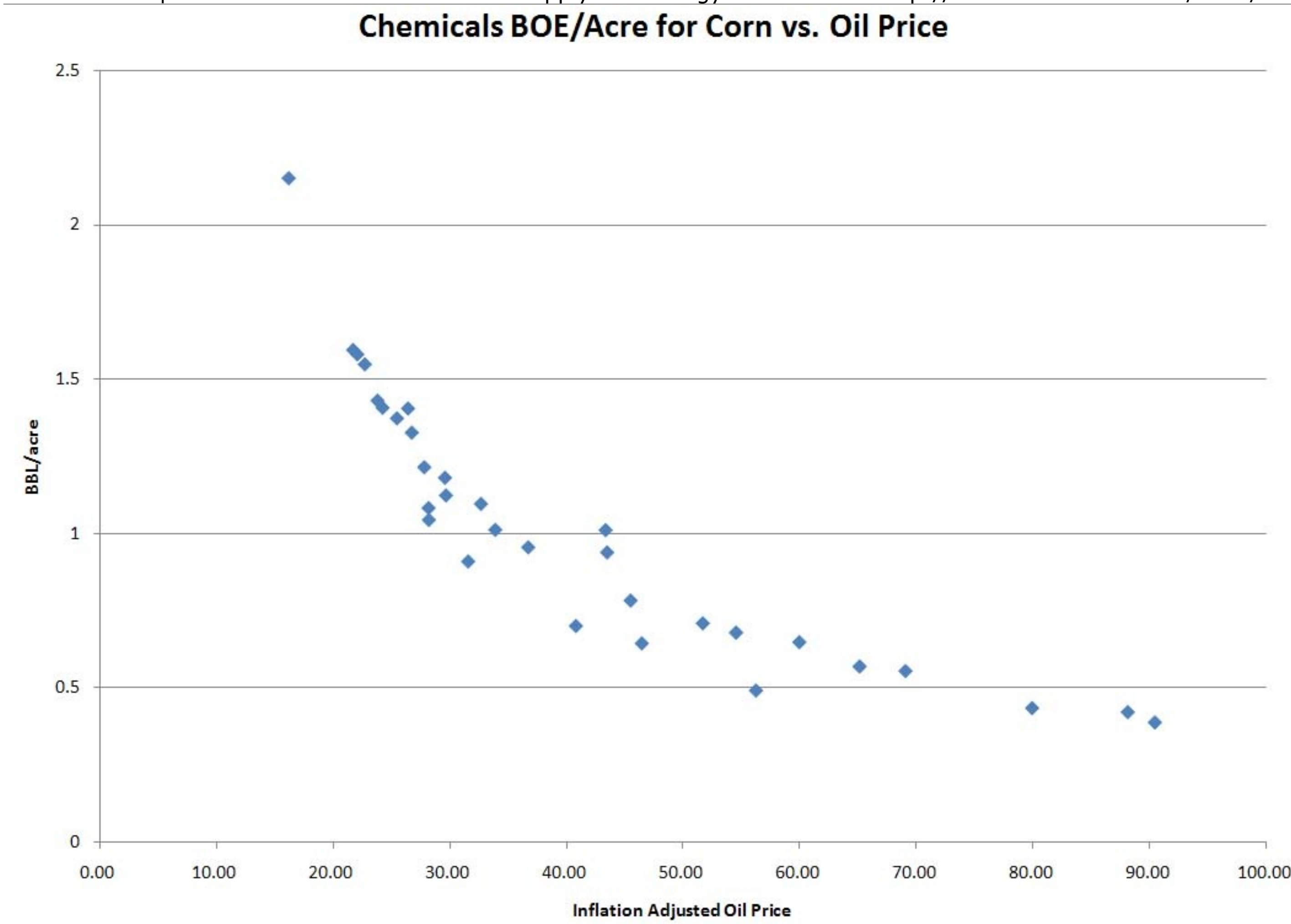

Rice Fertilizer Use per Acre vs. Oil Price
Fertilizer Costs/acre converted to BBL/acre
Inflation Adjusted Oil Price
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00

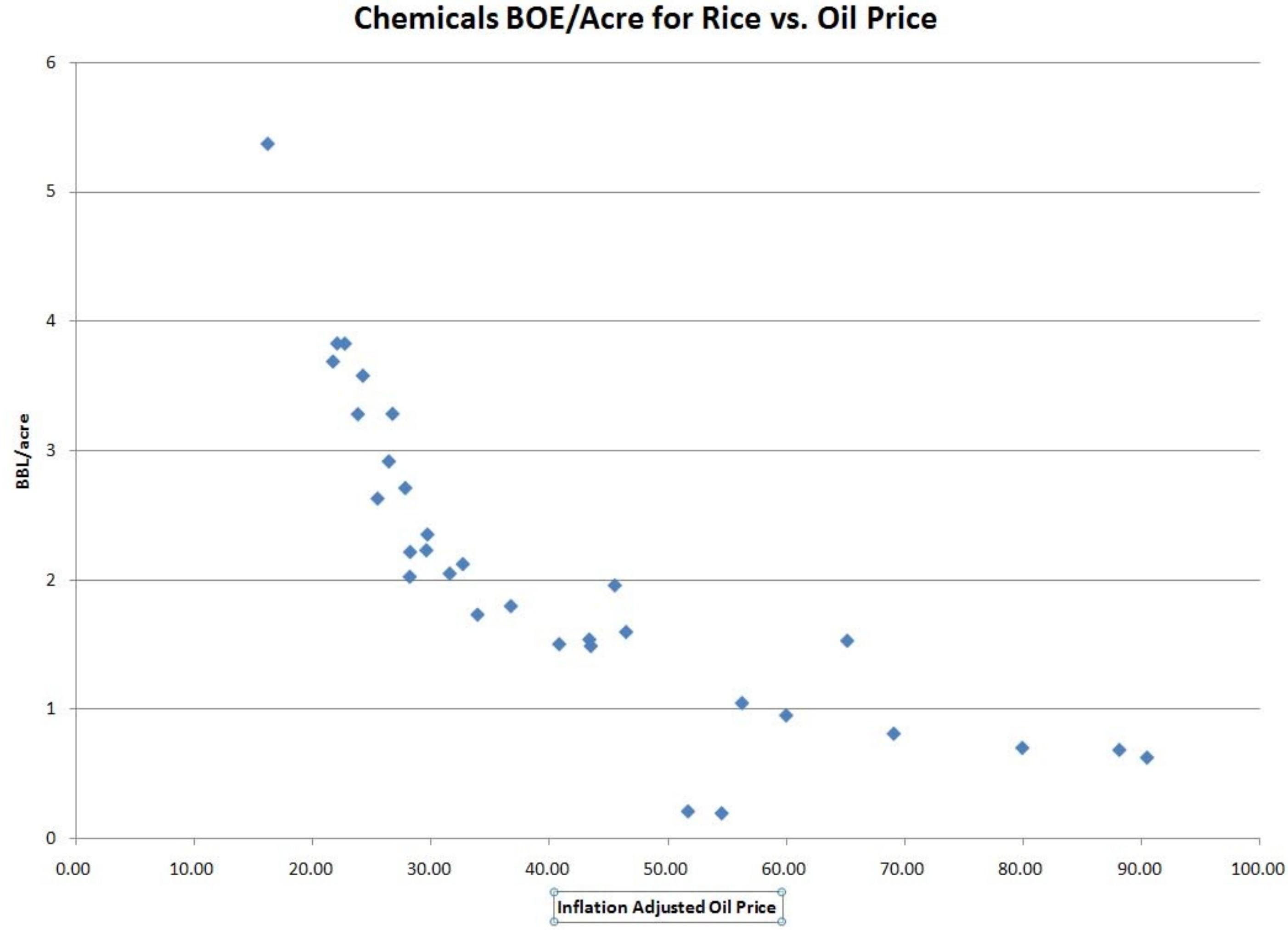


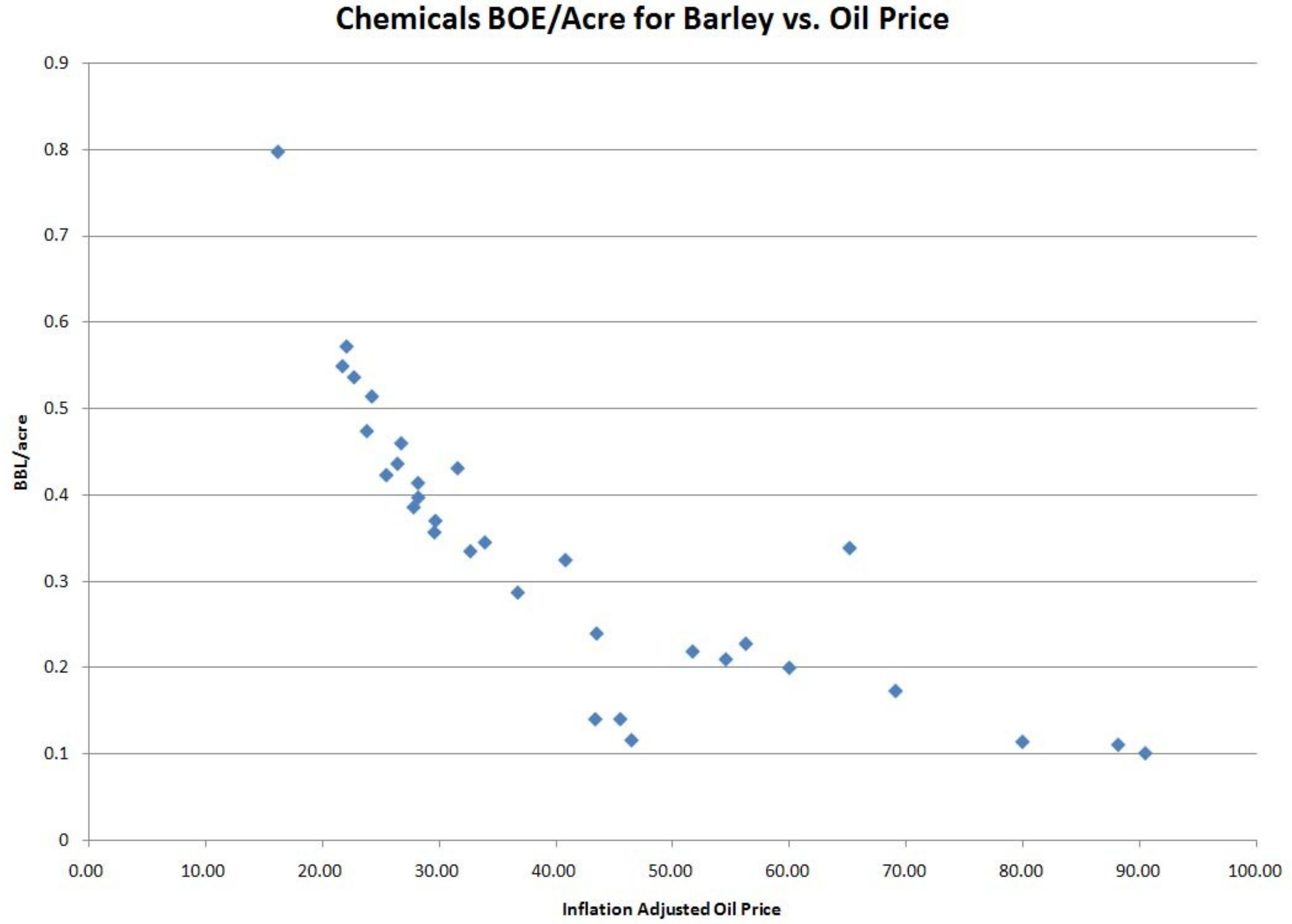
Looking at these charts we see more elasticity in the higher oil price regions. The use of fertilizer with wheat, rice and barley continue to drop as the price of oil goes up. Corn is a bit more complex and it isn't clear why. One sees two behaviors below the $45 oil price. But one thing is clear on all four graphs. Below $45 the application of fertilizer goes way up. This is not a phenomenon related to long term changes in the practices of fertilizer application. Even in the mid-1990s, the use of fertilizer rose more rapidly as the price of oil fell. It is clear that farmers are reluctant to go down in fertilizer use too rapidly as the oil price rises, but, this is the second place that they can cut when oil prices are high.

The next four charts show the elasticity of chemical usage. This includes insecticide. Clearly its use is even more elastic than is fertilizer. And once again we see a split behavior. Rapid rise of usage below $40/bbl and linear reduction above that value. We see this for each of the grains.


Chemicals BOE/acre for Wheat vs. Oil Price
BBL/acre
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Inflation Adjusted Oil Price


Chemicals BOE/Acre for Corn vs. Oil Price
2.5
2
1.5
1
0.5
0
BBL/acre
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Inflation Adjusted Oil Price


Chemicals BOE/Acre for Rice vs. Oil Price
BBL/acre
0
1
2
3
4
5
6
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
Inflation Adjusted Oil Price



One surprise in this data, at least it was surprising to me. One can't easily correlate yield (bu/ac) with oil price. Nor can one see a correlation between farm profits and oil price. The best reason for this that I can think of is that both yield and profits are subject to so many other variables than oil price. Rainfall (and when it occurs), temperature, crop disease, all play a role in both yield and profitability. The oil price signal gets swamped.

Another surprise was that crop yield didn't correlate with fertilizer use in the USDA data. One can have high expenditures on oil based items, only to have the crop fail; conversely, one can have spend little and have the other conditions simply perfect for maximizing yield. That may not be comforting when one looks at controlled experiments with fertilizer. This site reports tests of nitrogen fertilizer on 3 test plots in Montana. One test plot didn't respond to nitrogen, but the other two did. Here are the results from the other two.

Brady Mt,

N lb/ac	Yield bu/ac	Protein%	weight/ac	sulfur %
0	46.2	14.1	58.6	0.171
30	47.3	14.4	58.4	0.177
60	49.5	15.1	58.1	0.181
90	50.0	15.4	58.0	0.188

Sunburst, MT

N lb/ac	Yield bu/ac	Protein%	weight/ac	sulfur %
0	23.4	10.8	58.3	0.160
50	33.3	12.7	57.3	0.177
100	37.7	15.2	56.1	0.204

150	35.8	16.9	54.9	0.228

Studies in Kentucky also show a 3.5 bu/ac increase in wheatyield with nitrogen fertilizer.

And for corn, one can find this abstract

Proper fertility management in corn production is important both from an economic and environmental standpoint. A field study was conducted to investigate the effect of starter fertilizer on corn yield northern Great Plains. The experiment was established within a two-year corn/soybean rotation, with four replications. The experiment was carried out for four years (2000-2003). Starter fertilizer treatments consisted of four nitrogen (N) rates (0, 7, 14, and 21 lb N ac-1). These N starter treatments contained phosphorus (P) and potassium (K). An additional treatment of no starter fertilizer (no N, P or K) was also incorporated into the experiment. All starter fertilizer was applied at planting in a band 2 inches below and 2 inches to the side of the seed furrow. An additional 75 lb N ac-1 was applied side-dress at the V6 growth stage to all plots. Although the magnitude of grain yield varied for the four different growing seasons, largely due to rainfall, the yield trend was consistent with respect to treatment differences regardless of year. Comparison between the no starter (no N, P or K) treatment and the P and K treatment (no N + P and K) resulted in the largest yield increases, with yield increasing up to 36 % for the 2003 growing season. There was a significant positive response to increases in N rate for all years except the 2002 growing season, which was the lowest yielding year out of the four. Application of starter fertilizer can have a significant positive impact on yield and quality of corn grown in the northern Great Plains.

Experiments tell us that lack of fertilizer will reduce crop yields and that is exactly what oil prices cause--reduction in fertilizer. Why the difference? Precision application of fertilizer rather than the spray-it-all-over-the-place techniques have begun to come into play, minimizing the effect of lessened fertilizer application--so far. Eventually, even that might not be enough to avoid a drop in crop yield.

With corn, one of the interesting realizations is that a 19th century farm grew about 30 bushels per acre, while today, with our machinery we can grow up to 160 bushels per acre. How this is done needs some explanation. The first thing is that on a modern farm, 30,000 corn plants grow per acre. This is about 1.5 square feet per plant. This simply can't be done without machinery. I am in the process of purchasing a 100-acre farm. Let's say I wanted to plant corn by hand and achieve those densities. At 5 seconds per seed, it would take 41 hours to do one acre. And 173 days to do the farm. Of course, by having lots of children I can put them to work. With 10 children, I could do it in 17 days. This shows that without machinery, the plant densities will drop. A modern wheat field has 1.3 million plants. Clearly, without machinery, this is a throw-the-seed-out-there-and-hope-the-birds-don't-eat-it-all exercise.

So, having shown the problem of planting without machinery, we can see that any reduction of oil is likely to cause a serious drop in crop yield, leading to famine. When we can only drive our tractors 80% as much as we do today, it will effectively mean only 80% of the land will be under cultivation. And like everything else, we are being squeezed from two sides. The population increase requires a higher rather than a lower yield per acre. In a recent article *The Telegraph* spoke of this problem. After pointing out that since the 1950s, there has been an 11 percent increase in cultivatable land, yields have gone up 120 per cent. As they say, 'they aren't making new land anymore'. Ferguson further states:

“But can world food production keep pace? Plant physiologist Lloyd T Evans has estimated that "we must reach an average yield of four tons per hectare… to support a population of 8 billion". But yields right now are, as we have seen, just three tons per hectare. And a world of eight billion people may be less than 20 years away.” (Ferguson, 2007)

Irrigation

Many areas of the world are involved with irrigation to support the agricultural efforts. My former sister-in-law lives on a farm in western Nebraska. They tap the Ogallala reservoir to water their land. Over the many years, the water level has dropped forcing wells to go deeper. This has happened throughout the world as the farmers try to get water to grow their crops. Vacuum pumps (the ones with the handle) can only bring water up from less than 32 feet deep. If you go deeper, you need either a bucket system or electricity. And therein lies the rub. As energy supplies grow scarce, electricity will begin to become less and less reliable. Consider these guys from India. Notice the depth of their water wells.

"Since the 1990s, India has been a major net exporter of rice, shipping nearly 4.5 million tons last year.

"But annual yield increases began to slow over the past decade. Farmers cranked up fertilizer and water use, draining the water table. Many began planting two crops a year, taxing the soil. Punjabi area officials discouraged farmers from planting two crops and in some places outlawed it, but many farmers ignored them."

"I'm doing mischief against the government,' concedes Kanwar Singh, a second rice crop recently on a stretch of flooded land near the northern India city of Karnal. He says he now has to pump water from 300 feet below the surface, compared with 70 feet 10 years ago." 'In a year or two, maybe it will be finished,' he says." (Barta, 2007, p. A10)

and

"Lakhbir Singh, 35, this year planted aerobic rice for the first time. He says his costs have tripled over the past decade. His well was about 60 feet deep 10 years ago; now, it's down to 450 feet, and he has to use a

special submersible engine to help haul the water to surface. The health of his soil has deteriorated, so he's using more fertilizer." (Barta, 2007, p. A10)

If electricity becomes problematical, as it must in a post peak-oil world, pumping water from those depths will become difficult but not impossible. There is the tried and true wind mill. At [this site] one can find a table on vertical distances one can lift water with a given size windmill. To lift water 450 feet, as Lakhbir Singh requires, one needs a 14 ft-blade windmill and a 15-20 mph wind. With this, and an estimated 4-5 hours per day of pumping, he could raise 190 gallons per hour during the pumping time for a daily 1000 gallons per day. This is 231,000 cubic inches of water, or enough water to cover an area 231,000 sq. in. in area one inch deep in water. That is 1600 sq feet or 4% of an acre and one inch isn't enough water for most rice varieties. This would hardly be classified as large scale agriculture and I wonder if he could feed his family, much less feed mine.

It can't happen in the U. S., right? Wrong. There was a recent report in the Wall Street Journal talking about how Texas will begin to experience the electricity problems that California is now experiencing. Why? Because we won't build coal-fired electrical plants. For the farmers in the drier parts of Texas, pumped irrigation is the only way they can grow the food we eat. Thus, the effects of peak oil will spread even to our ability to obtain water for irrigation.

Agriculture and Slavery

In discussing these issues with a statistics professor friend of mine, he made a comment that made me think. I had told him my favorite statistic (Price 1995)

“Today, the extrasomatic energy used by people around the world is equal to the work of some 280 billion men. It is as if every man, woman, and child in the world had 50 slaves. In a technological society such as the United States, every person has more than 200 such "ghost slaves."

I also told him that the energy in one gallon of gasoline represents the physical labor of one human for 3 weeks. After hearing this, my friend then asked me if the modern world doesn't have slavery because of cheap energy. I must admit that was something I wish I had thought of. Slavery still exists in the world, but it exists in the poorer parts of the world. Looking at the calculation about planting corn above, one can understand the need for cheap labor, whether that labor is one's children or property. I must make it clear that I think this is absolutely horrible, but every society in the past was a slave-holding society. If we lose our energy and have to live the life they lived, are we naive enough to think our descendants will avoid the mistakes they made?

Conclusion

Peak oil represents a grave threat to our food supply, in my opinion. Few are aware of how important the petroleum industry is to the agricultural revolution in which we live. This is why I am currently trying to buy a farm. Consider this, prior to the agricultural revolution, estimates of hunter-gatherer population sizes, based upon anthropological data show that humans were quite few in number.:

"Measures of world population size on the eve of the transition to agriculture, some 12 000 to 10 000 years ago, come from estimates of the maximum population density that this way of life could sustain. These generally range from 5 to 10 million people, and the highest figure--calculated on the assumption that the world was 'saturated' with hunter-gatherers --is only 15 million." (Landers, 1992, p. 402)

Agriculture based only upon animal energy allowed the human population to grow to about 750 million by 1750 (Cavali-Sforza, 1994, p. 68). Peak oil will do several bad things to the world's energy supply. It will force us to use coal, and if one uses coal to replace oil, because coal will be used at a faster rate, the US turns its 200 year supply of coal into a 44 year supply (assuming that there really is a 200 year supply to start with). This implies that by the end of this century, we will no longer have fossil fuels with which we can foster global warming. Nor will we have fossil fuels with which to run our tractors and we will return at the very least to the 1750s. Going back to an animal-energy based economy means that approximately 5/6ths of us must die. The post fossil fuel world, lacking some new energy source, will consist of not many more than 750 million souls. What an ugly century this will be. While there are some long-shot grasps-at-straws possible replacements for fossil fuels, the political turmoil resulting from mass starvation may preclude their development and implementation.

References

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David Price, "Energy and Human Evolution", Population and Environment, Volume 16, Number 4, March 1995, pp. 301-19