In Defense of Irrigated Agriculture
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Irrigated agriculture is one of the most critical human activities sustaining civilization. The current world population of 6.8 billion people is sustained in a large part by irrigated agriculture. USDA statistics show that 17% of cultivated crop land in the United States is irrigated. Yet this acreage produces nearly 50% of total US crop revenues. According to the FAO the approximate 1,260 million ha under rainfed agriculture, corresponding to 80% of the world's total cultivated land, supply 60% of the world's food; while the 277 million ha under irrigation, the remaining 20% of land under cultivation, contribute the other 40% of the food supplies. On average, irrigated crop yields are 2.3 times higher than those from rainfed ground. These numbers demonstrate that irrigated agriculture will continue to play an important role as a significant contributor to the worlds food supply.
Water is increasingly in the headlines and irrigated farmland is increasingly to blame. Government subsidized "cheap water" from century old dams and water projects are not viewed a foresight but as taxpayer subsidies to farmers dismissing the positive effect on food supply and prices. Farmers are blamed for maximizing yield at the expense of natural resources as much a criticism of capitalistic philosophy as agriculture. The fact is that today's farmers are producing more food on less land than ever before. Given current trends in population growth and the loss of prime agricultural land to development this trend must continue if we are to maintain an adequate food supply for the world.
The critical environmental vagary farmers have to deal with is precipitation. Other environmental factors such as temperature, sunlight even insects and disease are far more regular. Thus Irrigation is a powerful mitigator of main environmental risk associated with farming. To this end farmers in drought prone areas make large investments in irrigation. The risk mitigation provided by irrigation goes beyond simple economic advantage to the farmer. Irrigation allows for a more consistent food supply and higher productivity. Recent studies have shown increased CO_2 sequestration, reduced N_2O emissions and more efficient fertilizer use associated with irrigation. The evidence in support of irrigated farming is compelling.

A) Drought and Famine
The causes of famine in the world are complex, often involving economic, political, and biological factors. Each of these factors paints the cause of famine with its own perspective.
Economically, famine is the failure of the poor to command sufficient resources to acquire essential food. The great famine in Ireland which began in 1845 occurred even as food was being shipped from Ireland to England because the English could afford to pay higher prices. The 1973 famine in Ethiopia also occurred as food was being shipped out of Wollo, the center of the famine, to Addis Abba because the capital city could afford to pay more.
Political causes of famine occur because of war, violence or poor public policy. The citizens of the social dictatorships of Ethiopia and Sudan in the 1970's and early 1980's suffered huge famines while the democracies of Zimbabwe and Botswana avoided them in spite of having worse drops in the national food production. This was done through the simple step of creating short term employment for the worst affected groups.
Biologically, famine is caused by the population outgrowing its regional carrying capacity to produce food resources. The failure of a harvest or the change in conditions such as drought can create a situation whereby large numbers of people live where the carrying capacity of the land has dropped radically. Interestingly, at a time when "industrial agriculture" is perceived as a villain, even portrayed as destroying the planet, famine due to crop failure is most often associated with subsistence agriculture, that is where most farming is aimed at simply supplying enough food energy to survive. This means that for farming to provide sufficient food it must be economically satisfying to the farmer not just in good years but year in and out.

Famine records indicate that farm programs that subsidize production may have a positive effect on famine reduction. Europe and the United States have not faced widespread famine due to crop failure in the past 200 years. Up until the middle of the 20th century Africa was not considered to be famine prone. Famine in Africa increased as the economics of agricultural pursuits has become less profitable. Africa does have an ample share of drought, soil problems, crop diseases and especially civil unrest and associated land issues. This has resulted in agrarian life to be uneconomic, and in some regions, fatal. It is the lack of this security that holds most of the blame for African food issues. Long term land and crop security could do much to relieve this.

Crop failures, whether due to natural or man made conditions, have been associated with famine since recordkeeping began. Manmade conditions most frequently include war, particularly attacks on land and farmers meant to starve the local populations. Natural crop failure occurs because of plant disease, such as occurred during the great potato famine, insects such as locusts and, most frequently, drought. Irrigated agriculture provides a buffer against crop failure due to drought.

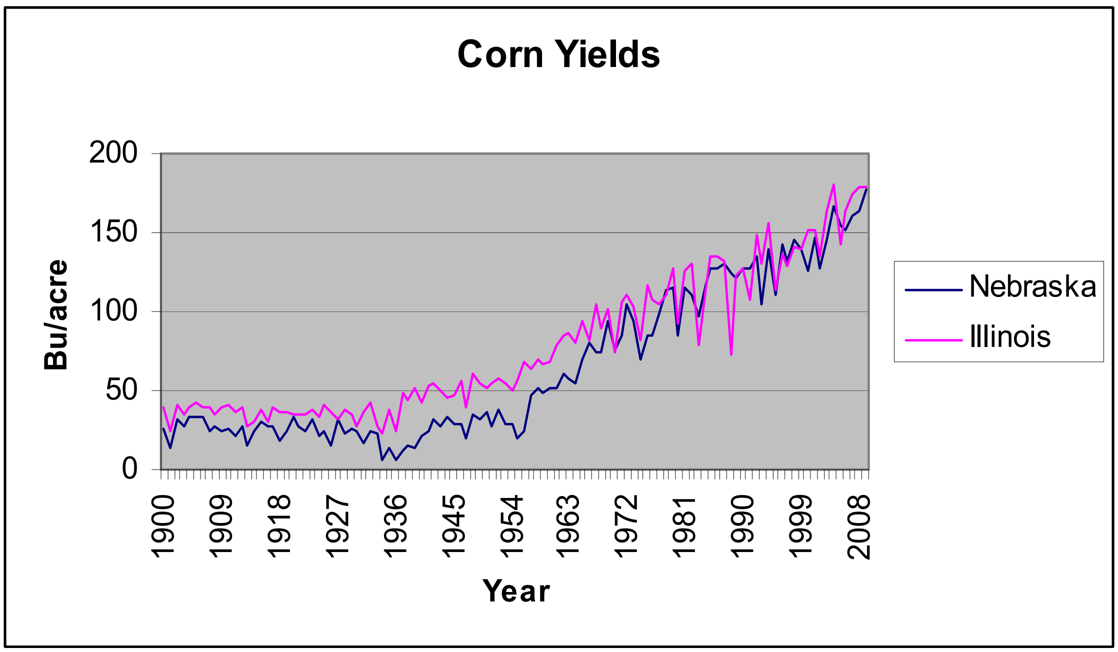

Figure 1. USDA corn yields data for Nebraska and Illinois. In the year 2007 Nebraska had over 80% irrigated corn acres while Illinois had less than 5% irrigated corn acres.

Corn yields from 1900 to 2008 was compared for the rain irrigated state of Illinois averaging over 30 inches per year rainfall and the dryer state of Nebraska with less that 15 inches rainfall on average. In addition, over the last 30 years irrigation has increases in Nebraska from 30% of planted corn in 1966 to over 80% of planted corn in 2008.

The yield data in Figure 1 can be roughly divided into three distinct segments. The relatively constant yields of 30 to 40 bushels/ acre that occurred from 1900 to 1933 covers the period when corn varieties were open pollinated. The rise in corn yields from the 1930's until the 1960's occurs concomitantly with the increased use of double cross hybrids during this time. The more rapid increase in yields from the 1960's until present day corresponds to the introduction of single cross hybrids.

A closer look at each segment offers some insight into the factors affecting corn yields in these two different environments. Figure 2 looks at the trends in the era from 1900 to 1930 when farmers only had access to open pollinated corn varieties. During this period there was some flood irrigation in Nebraska but it accounted for less than 10% of total corn acreage. During this period the total acreage planted to corn in these states was some 20% higher than that planted today, over 9 million acres in Nebraska and 13 million acres in Illinois. On average Illinois yielded about 10 bushels more per acre than Nebraska. It is clear from the data that the yields from Nebraska are more variable than the yields from Illinois. It is not possible to correlate yield to specific rainfall events because the timing of the rain is critical to corn yields but it can be said that greater variability in yields observed in Nebraska as opposed to Illinois can be related to the greater variability in rainfall found in this region.

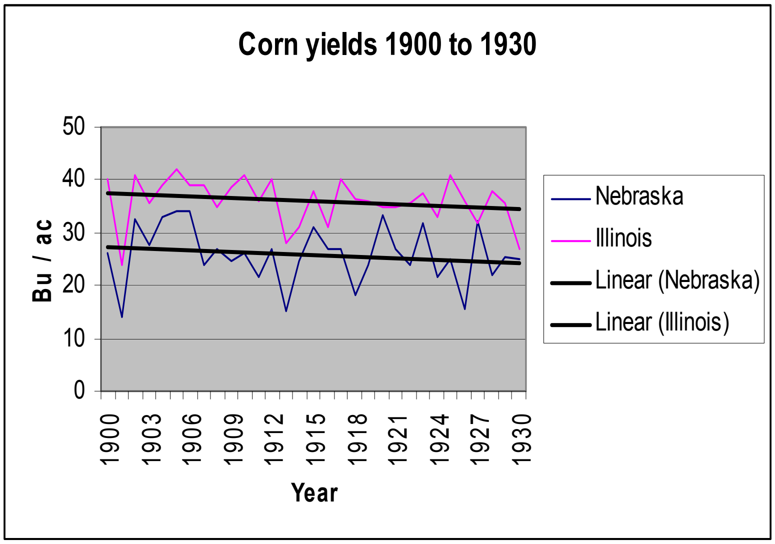

Figure 2. USDA statistics of corn yields in Illinois and Nebraska from 1900 to 1930.

The period from 1930 to 1935 corresponds to the drought that caused the dust bowl in the Great Plains. The collapse of corn yield in Nebraska is evident in Figure 1. The drought during this time did impinge upon Illinois but was much less severe in this region. This is reflected in the corn yield data. Following this period yields began to increase due to advanced genetics and better crop practices developed by the land grant universities (Figure 3.).

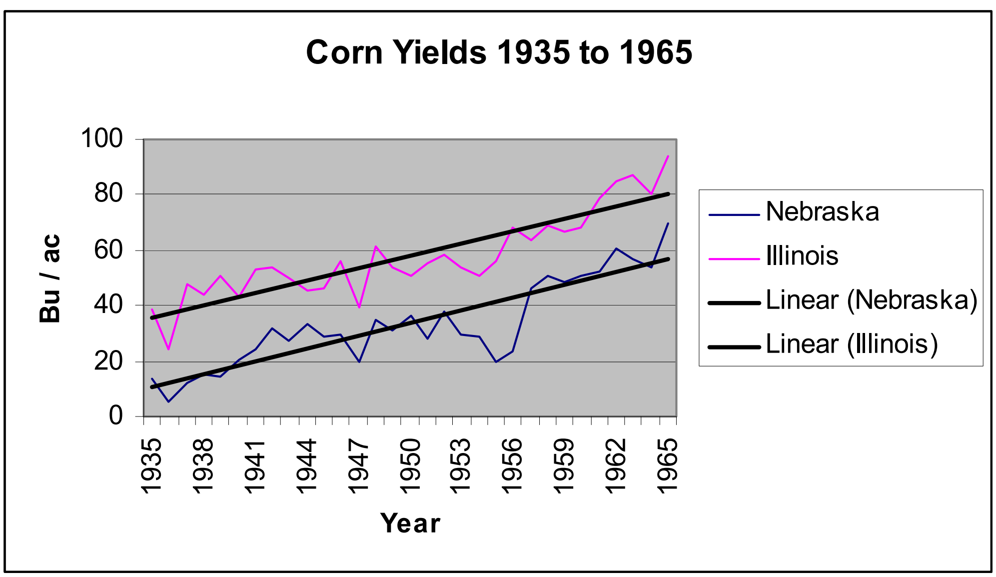

Figure 3. USDA statistics of corn yields in Illinois and Nebraska from 1935 to 1965.

Interestingly, the approximate 10 bushel higher yield observed for corn grown in Illinois compared to Nebraska was maintained during this period. Yield reductions due to a significant drought from 1952 to 1957 are obvious in this data. As was seen in the period 1930-1935, the effect was more pronounced in Nebraska relative to Illinois due to more variable precipitation in the more western state.
The period from 1965 to present is marked by a massive increase in irrigation in Nebraska. In 1966 there were 3 million irrigated acres while in 2002 there were 8 million acres. Over this time the area devoted to corn in the state of Nebraska was constant at a little over 9 million acres. This period also marked the largest increase in yields in both irrigated Nebraska and non-irrigated Illinois. This yield increase is often attributed to the "green revolution" of better fertilization methods along with improved varieties and crop protection chemicals. The reality is that the green revolution started as early as the turn of the century and started to take off in the 1930's. The large yield increases seen since the 1960's was the mainstreaming of the yield increasing technologies due to increased farm investment.

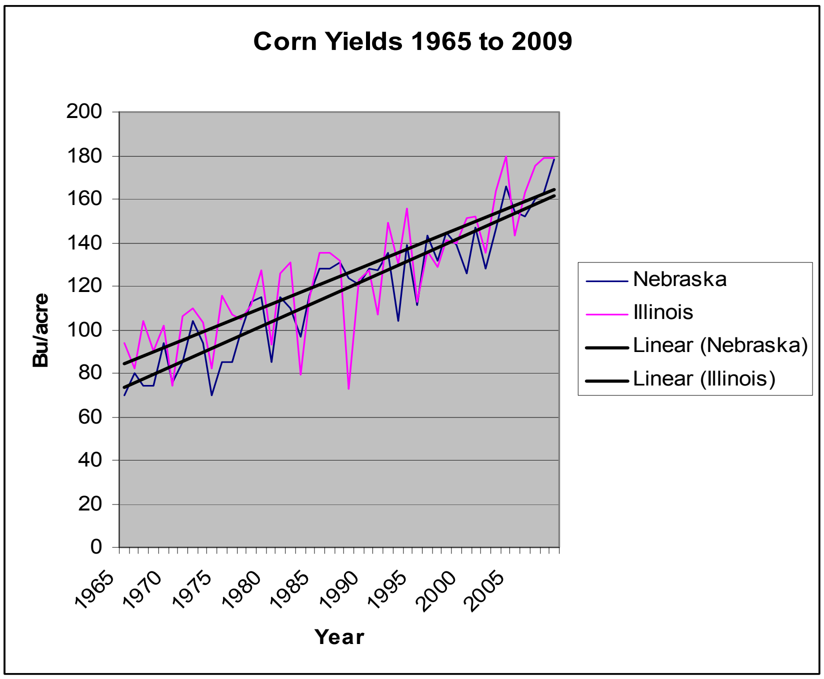

Figure 4. USDA statistics of corn yields in Illinois and Nebraska from 1965 to 2008.

The data in Figure 4 indicate that the average yield for the state of Nebraska is for the first time approaching the yield for Illinois. This suggests that irrigation, or the lack of it, was entirely responsible for the difference in yields between the two states. In addition over this time period the variability in yields is more pronounced in Illinois. A regression analysis confirms this giving an R squared for Nebraska of 0.85 while for Illinois a 0.68. This suggests that irrigation also reduces variability in yield.

B) Productivity of Irrigated land
According to the FAO, average crop yields for irrigated acres are 2.3 times those from rainfed areas. The actual yield increase will vary according to the region and the crop. In Nebraska the yield boost attributed to irrigation between 1992 and 2007 ranged from 10% for sorghum in 1998 to 268% for corn grown in 2002 (Table 1.) Corn wheat and alfalfa exhibited the greatest response to irrigation while sorghum and soybeans had a lower positive response. The high productivity of irrigated agriculture allows fewer acres to feed a larger proportion of the global population. Increasing productivity per acre is critical as farmland acreage continues to be converted to residential property.

Yield per Acre of Major Crops in Nebraska

	Corn for Grain (Bu.)		Sorghum Grain (Bu.)		Wheat (Bu)		Soybeans (Bu.)		Alfalfa Hay (Tons)	
	irrigated	non-irrigated	irrigated	non-irrigated	irrigated	non-irrigated	irrigated	non-irrigated	irrigated	non-irrigated
1992	144	117	101	93	49	29	45	41	4.5	3.4
1993	111	90	70	58	56	28	41	34	4.1	3.2
1994	153	113	109	97	55	34	53	45	4.5	3.2
1995	130	73	74	57	62	40	42	29	4.4	3.2
1996	156	115	106	94	53	35	50	43	4.8	3.3
1997	151	99	101	80	48	36	51	37	4.5	2.8
1998	161	119	104	94	68	45	51	41	4.8	3.4
1999	159	111	102	91	66	47	51	38	4.6	3.4
2000	154	84	98	69	63	34	50	30	4.5	2.6
2001	173	110	106	83	59	35	53	39	4.7	3
2002	166	62	83	48	63	30	51	29	4.4	2.3
2003	186	82	117	56	67	44	54	31	4.8	2.9
2004	186	134	110	78	66	33	54	40	4.7	2.9
2005	185	108	113	84	60	37	59	43	na	2.4
2006	185	101	109	77	67	32	59	42	na	2.1
2007	181	125	117	96	58	40	55	47	na	2.4

Table 1. Yield of irrigated and non-irrigated crops in Nebraska 1992 to 2007

The need for increasing yields on increasingly poor quality land is becoming more pressing as land development for housing increases. The United States looses two acres of prime farmland every two minutes. From 1992 to 1997, six million acres of agricultural land was converted to developed uses. This represents an area the size of Maryland. Much of this land is prime land.

Prime Acres Lost

State	87-92	92 -97
TX	234,300	332,800
OH	146,400	212,200
GA	110,900	184,000
NC	167,100	168,300
IL	67,900	160,900
PA	109,700	134,900
IN	75,100	124,200
TN	87,200	124,000
MI	72,700	121,400
AL	50,200	113,800
VA	59,800	105,000
WI	54,200	91,900
NY	36,900	89,100
SC	52,600	86,200
CA	73,800	85,200

Table 2 Farm acres lost by state

The rate of conversion of prime land was 30% faster than for non prime land. This results in more marginal land being put into production. In addition, most of the development is occurring in areas that receive significant natural rainfall. Of the top 12 states losing prime farm land only one, Texas, significantly relies on irrigation. This development forces more production into irrigated lands increasing the pressure on water supplies.

Development is also pushing agriculture to more marginal lands. Flat, well drained land is considered prime land for farming. It is also the least expensive to develop into housing and commercial properties. The Southern California Central Valley averages 10 to 15 inches of rainfall a year while the coastal valley including Watsonville and Salinas averages twice that amount. Yet housing is pushing vegetable production out of the relatively wet coastal valley to the dryer central valley where more irrigation is required. In another example, most of the best farmland in New Jersey is now covered by houses. This is occurring at a time when “buy local” is being promoted as the most sustainable food option. Loss of arable land is increasing as the world population gets wealthier. The general fact is that agricultural land and water use cannot compete economically with industrialized or residential uses. As discussed earlier farming must result in economic benefit for the farmers or crop production will not keep up with demand and food shortages will result. Water use policy must also include land use policy as part of the conversation.

C) Irrigated Agriculture and Environmental Quality

Researchers are beginning to consider the effect of irrigated agriculture on greenhouse gasses and air quality. Researchers in Idaho looked at the organic carbon stored in soils having long-term cropping histories of various crops. They found that irrigated pasture and irrigated reduced till cropping sequestered more carbon in the soil than native rainfed vegetation. Full tillage irrigated crops sequestered the least carbon. The authors concluded that if worldwide irrigated acreage were expanded 10% and the same amount of rainfed land were converted to native grassland that 5.9% of the total carbon emitted in the next 30 years could be sequestered. Studies of the effects of irrigation on the environment are new but show promise.

Another study compared drip and furrow irrigation relative to CO_2 and N_2O emissions. The CO_2 emissions were lower in drip irrigated compared to flood irrigated treatments but the differences were small (4%). More significantly, of the 100 pounds of N/acre added as fertilizer 18% was lost as N_2O in the furrow irrigated treatments compared to only 4% in the drip irrigated treatments. Although both gases are significant contributors to global warming N_2O is 300 times more potent than CO_2. Other studies indicate a positive relationship between irrigation and fertilization efficiency, supporting the conclusion that efficient irrigation reduces N_2O emissions.

Rainfall leaches nutrients from the soil. This is why, even in areas of high rainfall such as Florida, many growers practice plasticulture, the practice of using plastic mulch to better manage the soil environment. Strawberries and tomatoes are often grown in beds that are covered with plastic mulch. In addition to creating a clean surface for the fruit, this mulch prevents the natural heavy rains from saturating the soil and leaching out the applied nutrients. Irrigation, often drip irrigation, is then used to supply the necessary water.

Studies conducted in West Texas from 2000 to 2007 revealed that recovery efficiency of added N fertilizer ranged from a minimum of 12% in furrow irrigated fields to a maximum of 75% in fertigated fields. The relationship of total N uptake (pounds/acre) relative to yield in bales for all irrigation systems indicates that a bale of yield requires 40 pounds N per acre regardless of the treatment. Thus a furrow system that is only 12% efficient must apply 300 lbs N/bale/acre compared to 53 lbs N/bale/acre for a drip system that is 75% efficient. This saves money, potential runoff and N_2O emissions.

D) Irrigated Agriculture and Business planning

The risk associated with Agricultural production can be divided into three components

1) Systemic Risk – this is the risk associated with lost production most often associated with the weather, particularly rainfall but also insects and disease
2) Market risk – that associated with crop prices
3) Credit risk – usually associate with the low value of farm land relative to the cost of production.

The systemic risk is mitigated through the implementation of a crop insurance program, crop protection program, nutrient management program and irrigation program. The first three are usually treated as variable expenses while the irrigation system is a capital expense. The United States offers an excellent laboratory for considering the systemic risk associated with irrigated agriculture. In the Western arid states most crops cannot be grown without irrigation so irrigation is a necessary component of production. As you move East to the high plains, most crops can be successfully grown using natural rainfall but irrigation is necessary to obtain maximum yields (see Table 1). In this case there are measurable benefits and risks to choosing or not choosing to irrigate. The actual choice is many times dictated by incentives and subsidies but the result is more consistent high yields. Table1 indicates the risk for dryland farming of corn in Nebraska ranges from a minimum of 21 bushels to a maximum of 102 bushels per acre. The average difference is 58 Bu. This yield increase significantly reduces the risk associated with production in this region which is why over 80% of Nebraska farmland is irrigated.

Moving east of the Mississippi, rainfall is usually adequate for crop product except for exceptionally dry years. The decision then is whether to invest in irrigation as an insurance against 2 or 3 out of 10 dry years. This type of irrigation insurance is strongly dependent on the price of the irrigation system.

Market risks are mitigated through various selling contracts, futures, cash sales and hedge contracts. These instruments, while complicated, add significant upside potential to the farmer.

The credit risk of farming is usually associated with lenders but can affect farmers looking for funds to make significant investment in equipment such as irrigation systems.

In addition to risk mitigation, irrigation also allows for a more consistent yield year after year. This was shown to be true in irrigated Nebraska compared to Illinois (Figure 4). More consistent yields allow for more consistent application of market risk management tools such as futures and hedges. Also, the regular income associated with more consistent yields also improves the credit risk position of farmers seeking credit. This results in lower rates and better profitability. Finally consistent yields and revenues contribute to better business planning on a longer time scale, resulting in increased resource efficiencies.

Conclusion

Irrigated agriculture is critical to maintaining and growing the world's food supply as population grows. Analysis of yield data from Nebraska and Illinois indicates that irrigation mitigates the effects of drought, the number one environmental factor reducing yields. In addition irrigation results in more consistent yields which allow for better business planning particularly with regard to market dynamics. Prime agricultural land is being lost to development at an astonishing rate. Irrigation improves agricultural productivity particularly on marginal ground. This is necessary to meet future food needs in the face of reduced growing area. Irrigation may also help sequester carbon dioxide, reduce N_2O emissions from the soil and reduce fertilizer needs. This is not to say that water supplies, both ground and surface, need not be managed. Water must be available for people, industry, nature and food. Food is critical because it is the abundance of food that sustains people and industry and allows us the freedom to consider and preserve nature.

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