Sub-Irrigation Yield Effects and Farm Profitability

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In areas where both subsurface drainage and irrigation are needed to optimize crop production, a Sub-Irrigation (SI) system could be the viable solution. By stabilizing crop yields, these systems can reduce and optimize other crop input costs resulting in an increase farm profitability. In addition, these systems have a smaller environmental footprint than other drainage and irrigation methods. This technical brief summarizes observed yield impacts of SI, water quality and environmental benefits, and an example economic analysis.

INTRO

Excess moisture and drought are the leading causes for corn loss in Iowa accounting for 67% of the total crop. [i] SI helps to eliminate both of these factors when properly managed. Factors influencing corn and soybean yield response to SI include weather conditions, drainage system design, management intensity, soil type, and device spacing.

WATER QUALITY

Agricultural drainage systems provided for the conversion of millions of acres of marginal land into highly productive, profitable farmland. This extensive adoption of subsurface drainage can also be correlated with an increase in nutrient loading to some water bodies, [ii] [iii] [iv] [v] and may contribute to both local and large-scale water quality impairments.[vi] [vii] [viii] Conservation practices, such as Drainage Water Management (DWM), could help mitigate some of these negative effects by reducing nutrient losses from farm fields. [ix] [x]

Drainage Water Management enables producers to temporarily raise the tile outlet level and decrease drainage water volume. [xi] [xii] [xiii] Researchers estimated DWM could be implemented on 11.9 million [xiv] to 30 million acres [xv] of cropland in the Midwest. From that suitable land, the principle receiving waters are the Gulf of Mexico and the Great Lakes, both of which have significant nutrient impairments. The installation of DWM systems provide crucial off-site environmental benefits by reducing those impairments while offering significant economic returns, as will be discussed in this document. Recognizing the value of DWM for improving water quality, the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) provides financial assistance to install control devices used to manage these systems.

SI YIELD AND OTHER BENEFITS

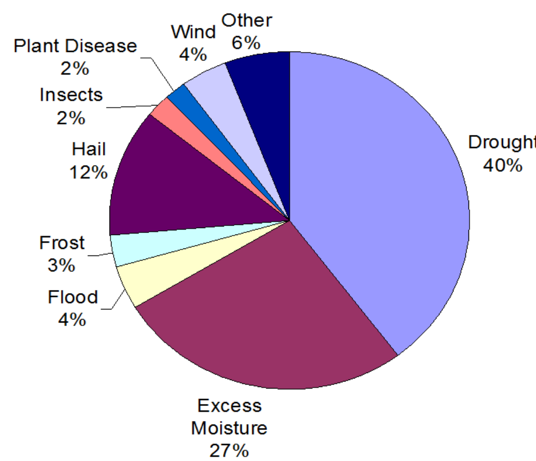

Figure 1. Corn Loss in Iowa from 1948-210. Diagram courtesy of Chad Hart, Iowa State University [i]

Corn grain yields are highest when the plant is never in a completely saturated soil. [xvi] A study compared a field containing SI to a field containing only subsurface drainage over nine years on a clay pan soil (restrictive layer desirable for SI) in which, on dry seasons, corn yields of the SI field where found to have increased by 108% compared to the drainage-only field. On an overall wet year, however, the yield difference was negligible. [xvii] [xviii] While yield impacts will vary from year to year, average increases over a 12 year study in NW Ohio were 35%. [xix] SI only provides the amount of water needed by the plant, thus it is extremely beneficial in years with little precipitation.

The biggest advantage with SI is the ability to achieve consistent yields (illustrated in Figure 2). Regardless if it is a wet or dry year, maximum yield potential can be reached with SI. In a Sub-Irrigation (SI) system the same tile is used to deliver water to the crop during the dry part of the growing season and remove excess when it is too wet. A water source is used to supply water into the tile system, allowing the producer to drain and also maintain the system. A control structure is used to create the head pressure needed to distribute water through the laterals and into the soil profile. Capillary action pulls the water upwards into the root zone.

For soybeans, one study showed that sites with SI experienced an average yield increase of 64%, compared to sites with subsurface drainage only. [xx] Another study found SI contributed to a 58% yield increase in soybean production, compared to non-irrigation. [xxi] The largest increases contributing to these averages occurred over dry growing seasons and in ideal soils. A return on investment study showed an SI system in 2012 increased soybean yields by 36 bushels per acre on average leading to gross returns over $500 per acre. [xxii] Average increases in the NW Ohio study showed on average 17% increase over 10 years of monitoring soybeans. [xix]

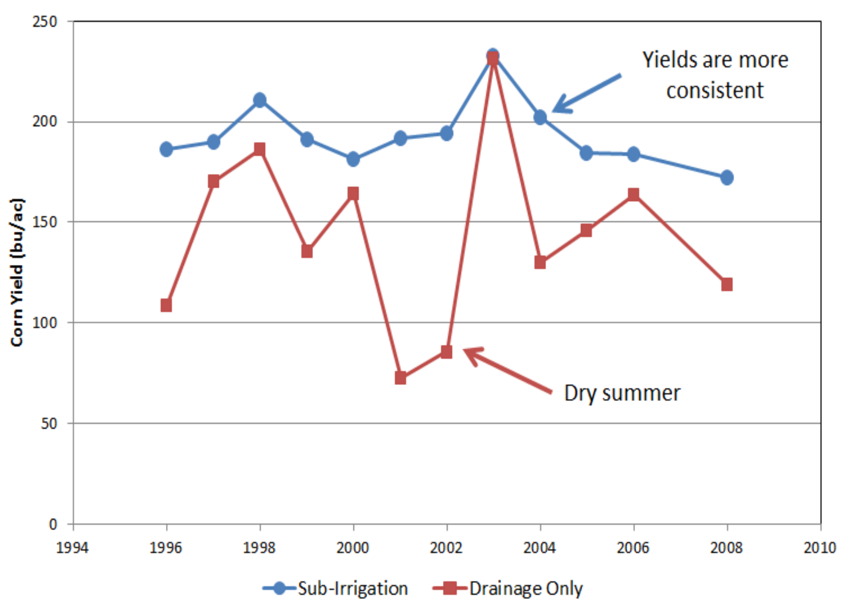

Figure 2. Corn Yields in SI vs. Drainage Only in Ohio. [xix]

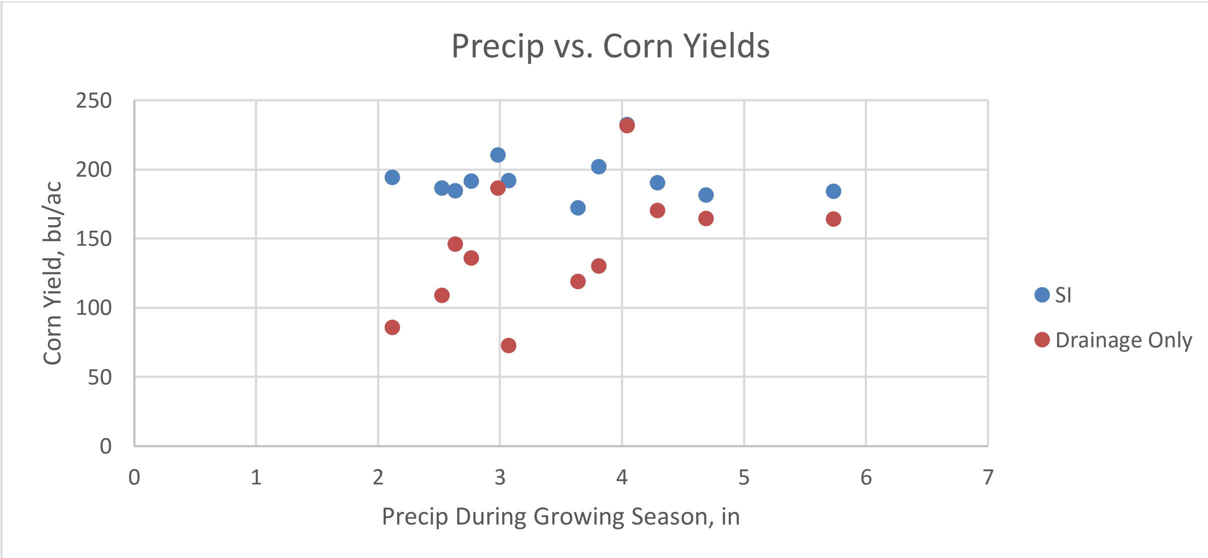

Figure 3: SI vs Drainage only during growing season in Ohio [xix]

Sub-Irrigation has many major advantages other than yield boosts over conventional irrigation. The existing infrastructure (with closer tile line spacing) can be used to deliver the water instead of purchasing an additional irrigation system, therefore the use of SI is much more energy efficient than conventional overhead irrigation (OI).[xxiii] SI provides a more intensive drainage system when removing ground water is required. You have the ability to hold water and nutrients back in the system both during growing and fallow seasons and reduce flooding during large rain events.

Sub-Irrigation is also much more water efficient than OI. Water is delivered where it is needed for the crop rather than evaporating during spray or from the surface as with conventional application. It delivers only the amount needed to the root zone, at rates 1 to 4gpm. At peak consumption, corn will use around 7gpm per acre. The reason all the water is not supplied is because the plant will get available water from an unsaturated, but moist, zone in the soil layer.[xxiii] Due to this, the risk of nutrient leaching, soil erosion, and water pollution is greatly minimized by SI.

Sub-Irrigation systems have been proven to reduce water by up to 40-50%,[xxiv xxv] along with lower energy requirements and lower maintenance cost than OI systems. SI is more resilient to storms, weather variations, and harder for thieves or vandals to disrupt, resulting in more consistent yields

SI FIELD REQUIREMENTS

Sub-Irrigation requires the "three S's" to be successful; compatible soil types, favorable surface topography, and a convenient water source. Proper soils will be poorly drained with a restrictive layer beneath the tile line. If a perched water table is present, it will act as the restrictive layer for the system. Ideal surfaces should have uniform slopes of less than 1%. Steep or undulating ground makes the systems more expensive to install and difficult to maintain. Structures are required for every one foot in elevation change, so a flat surface will be much more economical for the producer. Lastly, access to a water source needs to be considered. Wells, adjacent streams, and retention ponds are common sources currently being used.

If the infrastructure for DWM is installed it is only a short step to upgrading the capital investment needed to provide for SI. A study showed that tile spacing from 20-to 45 feet with lower water rates, around 2gpm, were projected to attain higher yields in corn. [xxvi] This is a closer spacing than traditional tile lines. Upgrades required for an efficient SI system include 1) optimal lateral spacing to provide increased drainage and SI response 2) a pump system to deliver water to the high point in the system for distribution throughout the tile lines 3) a water source and 4) water level control structures.

SYSTEM COSTS

The cost per acre of installing an SI system depends heavily on the cost of providing a water supply. Water sources commonly used are ponds, rivers/streams, and deep wells. The water storage should be able to supply water at a rate of 5gpm per acre. This rate is needed to fill the system; it is then dropped to 2gpm per acre for irrigation purposes by using variable frequency drive (VFD) pump motors.

New System Scenario [Assumptions: uniformly sloping square 80 acre Sub-Irrigated field, lateral spacing at 30ft, 4ft elevation change over entire field, designed on 1ft management zones]:

1867' of 10" main @ $5.25/ft.* = $9802

116,175' of 4" laterals @ $0.85/ft.* = $98,745

1 stop-log water control structure = $1,000

3 in-line 10" Water Gates @ $750/structure = $2,250

Deep Well [xxvii] = $15000

Hollow-shaft deep well turbine pump [xxvii]

(230V, 3-phase, 3450rpm, 75% efficient) = $7,000

Manifold = $1,000

Water delivery pipe = $2,000

System Scenario Upfront Cost = $136,797 or $1,700/ac

Retrofit Scenario [Installing an SI system on previously existing tile, same assumptions as above, tile was previously installed on 60ft spacing] ***This analysis assumes the existing tile infrastructure has been paid off.***

58087' (splitting current spacing) of 4" laterals @ $0.85/ft. = $49375

**all other costs such as structures, wells, etc. are the same

Typical System Upfront Cost = $77,625 or $970/ac

ECONOMIC ANALYSIS

The field for this analysis will have the same characteristics and costs as the list above. The new cost for this system would be $1700/ac. The retrofit cost of a current drainage-only field to SI will be $970/ac. The baseline for the current yields will be 180 bu./ac for corn and 50 bu./ac with beans. Iowa crop price averages for the years of 2012, 2013, and 2014 were used to calculate return on investment. [xxii] Return on investment was achieved when the initial investment was paid off from extra earnings contributed to yield increases. To get a representative example, corn yields will be analyzed during years where a 35% or 50% yield increase occurred. All soybean yields are analyzed on years where a 20% or 40% yield increase took place. The corresponding yield increases were then averaged to produce the number of years for achieving a return on investment. Our findings are outlined in the tables below.

Grain Prices ($/bu.)		
Year	**Corn**	**Beans**
2012	$6.67	$14.54
2013	$4.45	$13.38
2014	$3.71	$10.03

(1)

Years for Return on Investment for Average Corn Yield Increase			
Price (per bu.)	**$6.67**	**$4.54**	**$3.71**
Retrofit	2	3	4
New	4	5	6

(2)

Years for Return on Investment for Average Soybean Yield Increase			
Price (per bu.)	**$14.54**	**$13.38**	**$10.03**
Retrofit	5	5	7
New	8	9	12

(3)

Tables 1, 2, 3. Shows number of years until return on investment for corn and soybeans on both new and retrofit systems figuring different price scenarios and average yield increases.

Based on this preliminary analysis, yield increases associated with SI could cover the installment costs within a short period of time. With corn, new SI system costs could be recovered as quickly as 4 years. For soybeans, new system costs could be recovered in as little as 8 years. Retrofit returns will be noticeably quicker because of lower initial costs, assuming the existing tile is paid off.

DWM/SI Nutrient Benefits

When used in conjunction with controlled drainage during vital points in the year, such as immediately after fertilizing, sub-irrigation can reduce nitrate losses. One study compared DWM (only), SI (with controlled drainage), and free drainage and found that the SI tests reduced N losses up to 66% compared to free drainage, while DWM contributed only 44% reduction compared to free drainage. [xxviii]

A study of clay pan soils using a DWM system revealed that NO_3—N loss in tile drainage water was reduced by 78-to-85 percent in two out of four years due to a reduction in outflows. [xxix] A similar study reported 80 percent removal of phosphorus in managed drainage systems compared to free flowing drainage. [xxx] SI and DWM use the same method of draining, so similar results can be expected for SI systems.

In a 2-year study performed by Fisher et al. (1999)[xx], in-soil NO3-N losses were found between the root zone and tile lines (30-75 cm) where the soil is constantly saturated, contributing to less deep-seepage of nitrogen due to denitrification.

It can be assumed that sub-irrigation would have further reduced N losses as the soil would have been fully saturated at all points in the cropping season, leading to more denitrification.

Many studies show that nitrogen loss from agriculture can be reduced, both by reducing drainage outflows, and by forcing denitrification in the deeper soil profiles, therefore, not only is DWM/SI a benefit to producers, but it can also have positive environmental benefits as well.

Since Sub-Irrigation (SI) is typically installed with DWM in mind, it can be an effective strategy for reducing nitrate losses from farm fields. Yield increases associated with SI can cover device installation costs.

- ***Up to 30 million acres*** *of Midwest cropland is suitable for DWM/SI in the Midwest watersheds.*
- *Potential on-farm economic benefits could be maximized by taking into account characteristics that influence SI yield effects, including* ***drainage system design, device placement, and management intensity****.*
- *Reports of over* ***$500/acre*** *for soybean returns have been reported with SI.*
- *Sub-Irrigation reduces* ***water usage between 30 and 40%.***
- ***Wetlands*** *can be incorporated to 1)* ***reduce release of sediments and nutrients*** *2) promote wetland* ***vegetation*** *and* ***wildlife/waterfowl habitat*** *and 3)* ***enhance yields as a potential irrigation source****.*
- ***NO_3-N and Phosphorus (P)*** *in the drainage water can be greatly reduced due to the reduction of drainage.*

The nitrate reduction potentials come from the respective peer-reviewed articles. Cost values were compiled by researching design criteria and determining the items needed the 80 acre field given in the analysis. These values will vary depending on the project size and site specific criteria.

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