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Calculating Crop Nutrient Value From Irrigation Water Inputs: A Survey of Southeast Missouri Irrigation

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Approximately 600,000 acres of cropland are irrigated annually in Southeast Missouri. Agronomic benefits from timely irrigation practices are well known by agricultural producers in the region. A large, shallow water supply ensures inexpensive irrigation, making it a cost effective management practice.

Public concern runs high over water quantity and quality. Irrigation water sometimes contains elements and compounds such as nitrate or sodium that are undesirable in terms of human consumption, plant growth or soil environmental processes. However, irrigation water also contains elements or compounds that are essential for plant growth, such as nitrate, phosphate, potassium, sulfate, calcium, magnesium, iron, zinc, copper and manganese. Proper crop nutrient management often includes fertilization of some of these nutrients. Most producers do not consider irrigation water nutrient concentrations when developing a fertilization program. This overlooked source of plant nutrients is important and can save producers money and prevent adding of nonessential quantities of nutrients to the agri-ecosystem.

The purpose of this guide is to educate irrigators to the potential nutrient value of their irrigation water. Also included is a summary of an irrigation well survey conducted in 1987. Included in the survey are the Southeast Missouri counties of Butler, Mississippi, New Madrid, Pemiscot, Ripley, Scott and Stoddard, which contain large irrigated acreages.

Calculations

When analyzed, most elements present in water samples are reported in parts per million (ppm) units. To convert irrigation water constituents from ppm to pounds applied per acre requires the following calculation:

- 1 acre-foot of water = 326,000 gallons water
- 1 gallon water = 8.31 pounds water
- Therefore, 1 acre-foot of water weighs 2.7 million pounds
- ppm nutrient x 2.7 = pounds nutrient added per acre-foot

Example calculation

- water sample contains 5.3 ppm sulfate (SO_4)
- a rice crop requires 3.5 acre-feet of water
- 5.3 ppm x 3.5 acre-feet x 2.7 pounds = 54 pounds SO_4

- SO_4 contains 1/3 sulfur (S) and 2/3 oxygen (O)
- 54/3 = 18 pounds S added per year through irrigation watera rice crop requires approximately 15 pounds S per year

> **Note**
> the irrigation water supplied 100 percent of the rice S needs.

From this calculation it is obvious that irrigation water typically provides essential crop nutrients. Irrigators are advised to test wells periodically to take advantage of this "free" fertilizer. With water testing programs being developed throughout the United States, it should not be difficult to have wells tested. Use a reputable private or public laboratory that specializes in water testing. If only crop nutrients (not pesticides) are analyzed, then the cost of water testing should be minimal. Unless point source contamination has occurred, groundwater generally will contain similar amounts of essential plant nutrients over a small geographic area the size of most farming operations. Therefore, if sampling occurs away from potential point sources (feed-lots, fertilizer storage areas, etc.), then a representative water sample can be obtained from one or two well locations.

Table 1
Average values of irrigation water compostion by county and the entire survey region

Variable	Butler County	Mississippi County	New Madrid County	Pemiscott County	Ripley County	Scott County	Stoddard County	Region average
Temp. degrees F	58		57		62	67	59	60
Depth (feet)	113	100	93		56	70	102	103
pH	7.6	7.2	7.2	7.2	7.4	7.8	7.3	7.4[1]
E.C. mmhos[2]	0.5	0.3	0.3	0.5	0.4	0.2	0.5	0.4[1]
NO_3-N ppm	0.9	3.3	2.1	0.6	0.8	1.3	1.9	1.6[1]
SO_4 ppm	3.1	4.5	7.1	11	5.3	10	7.2	6.0[1]
PO_4 ppm	0.6	0.4	0.9	0.6	0.0	0.5	0.0	0.4
K ppm	1.8	3.6	3.7	1.9	1.6	1.3	2.0	1.4
Ca ppm	249	52	62	81	269	225	115	161[1]
Mg ppm	9	16	13	21	6	1	19	12[1]
Na ppm	12	8	11	9	10	7	19	13[1]
Fe ppm	4.5	1.6	0.5	1.1	1.8	1.5	2.2	2.5[1]
Zn ppm	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0
Cu ppm	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.1
MN ppm	0.8	0.4	0.4	0.4	0.6	0.6	0.5	0.6

[1]Denotes elements which had variation across the survey region and have agronomic importance. This variation is illustrated by cootour maps (Figure 1 to 8).
[2]Electrical conductivity, measured in units of mmho per centimeter.

1987 Southeast Missouri irrigation well survey

In 1987, an irrigation well water survey was conducted by MU Extension personnel to identify the nutrient content of irrigation waters in Southeast Missouri.

The survey was co-funded by the Missouri Rice Council and the Missouri Soybean Merchandising Council. Therefore, regions sampled were those where rice/soybean rotations are prevalent. A total of 272 wells were sampled in the seven counties. Data collected from each water sample were: well depth, water temperature, water pH, and nitrate, sulfate, phosphate, potassium, calcium, magnesium, sodium, iron, zinc, copper, manganese and salt content. Due to high costs, water biological and pesticide composition was not analyzed. Average county and survey nutrient concentrations are listed in Table 1.

General trends showed that irrigation water phosphate (PO_4), potassium (K), zinc (Zn) and copper (Cu) did not vary across the survey area and were below levels necessary for crop growth. Calculations for total phosphorus and potassium supplied by one acre-foot of irrigation water using regional average concentrations are as follows:

- 0.4 ppm PO_4 x 2.7 = 1.1 pounds PO_4
- PO_4 is 33 percent P; therefore, 1 acre-foot of irrigation water would supply less than 1 pound P
- 1.4 ppm K x 2.7 = 3.8 pounds K applied per acre-foot of irrigation water

A 150 bushel per acre corn crop requires approximately 45 pounds phosphorus and 200 pounds potassium. Given the above calculations, it is estimated that irrigation waters in Southeast Missouri potentially can contribute less than 2 percent of the nutritional phosphorus and potassium needs for corn. Water manganese concentrations were also uniform across the region, but were high enough to partially provide crops with this essential micro-nutrient. Water pH, electrical conductivity (E.C.), nitrate-nitrogen (NO_3-N), sulfate (SO_4), calcium (Ca), magnesium (Mg), sodium (Na) and iron (Fe) concentrations were variable across the region with most present at levels high enough to influence crop production.

Contour maps (Figures 1 to 8) were developed for these components. County average irrigation water nutrient composition and regional contour maps were developed to identify general trends and may not be representative of site-specific wells located within counties or map unit delineation areas.

Due to low buffer capacity of most irrigation waters, water pH usually will not influence soil or plant systems. However, pH values in most of Scott County and near the St. Francis River in Stoddard and Butler counties approached alkaline levels (Figure 1). Producers should know the pH of their irrigation water, especially if agri-chemicals, some of which can be adversely affected by water pH, are mixed with these waters. Producers should check herbicide labels for optimum mixing water pH ranges.

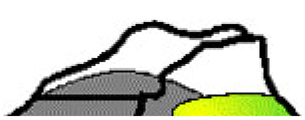

Figure 1
Irrigation water pH concentration gradients in southeast Missouri.

Water nitrate concentration has received much attention environmentally over the past several years. However, nitrate contained in irrigation water will provide crops with part of their nitrogen needs. If care is taken to prevent excessive runoff, most nitrate delivered through irrigation water is available to crops. Southeast Missouri irrigation waters varied in nitrate content (Figure 2), but in all cases contained nitrate-nitrogen at levels accepted by the EPA for drinking quality standards (less than 10 ppm). Areas of highest nitrate concentration were central Stoddard County and the tri-county region southeast of Sikeston. Using the Mississippi County average irrigation water nitrate concentration (highest nitrate testing county), it is calculated that 3.3 ppm NO_3-N x 2.7 = 8.9 pounds N is added per acre-foot of irrigation water.

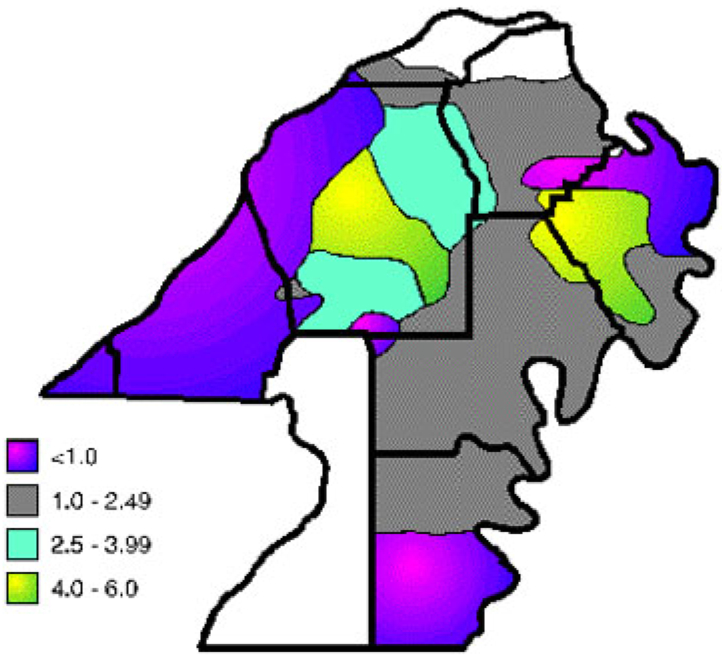

Figure 2
Irrigation water nitrate-nitrogen concentration gradients (ppm) in southeast Missouri.

A 150 bushel per acre corn crop requires approximately 240 pounds of nitrogen per acre. Therefore, irrigation waters in Southeast Missouri supply less than 5 percent of a corn crop's nitrogen nutritional needs.

Sulfur is an essential plant nutrient required in quantities approximately one-tenth of those needed for nitrogen. Most crops require between 10 and 20 pounds of sulfur per acre. As irrigation water approaches 5.0 ppm sulfate, crops receiving irrigation will benefit in terms of sulfur nutrition. (See example calculation.) Most irrigation water in Southeast Missouri contains sulfate concentrations approaching or exceeding 7.5 ppm (Figure 3). Generally, irrigated crops grown in Southeast Missouri may not require sulfur fertilizer inputs.

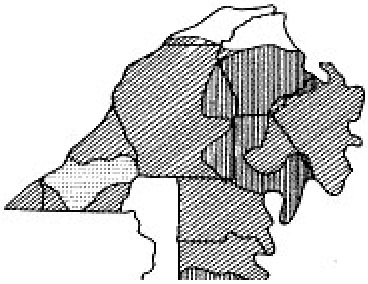

Figure 3
Irrigation water sulfate concentration gradients (ppm) in southeast Missouri.

Calcium is a nutrient required by all crops, but rarely is calcium fertilization needed. Calcium usually is added to soils in large quantities via agricultural limestone, or contained at soil clay adsorption sites or in clay mineral composition. Calcium additions through irrigation water sources in Southeast Missouri are appreciable and commonly approach 400 ppm (Figure 4). Some of this calcium may be fixed by soils or lost through leaching, but a large amount should be readily available to crops. High amounts of calcium in irrigation water combined with appreciable amounts of carbonate (CO_3) (not tested in the current survey) will give the water some agricultural limestone value. An example calcium carbonate equivalent (CCE) calculation for irrigation water using the Butler County average calcium concentration, and assuming all calcium is associated with carbonate (maximum possible CCE), is given below:

- 249 ppm Ca x 2.7 = 672 pounds

Ca applied per acre Calcium Carbonate is 40 percent Ca and 60 percent carbonate. Therefore, 672/0.40 = 1,680 pounds or 0.84 tons potential CCE applied through 1 acre-foot of irrigation water.

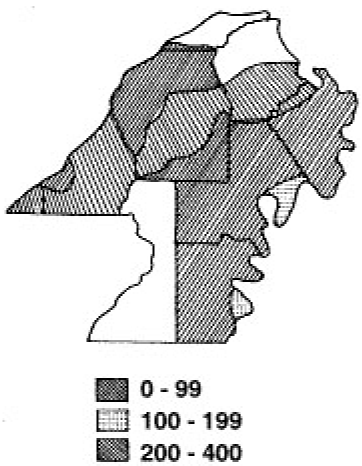

Figure 4
Irrigation water calcium concentration gradients (ppm) in southeast Missouri.

Given the high amounts of calcium, especially in a diagonal running northeast from Ripley County through southern Scott County, it is reasonable to expect that irrigation water is supplying appreciable agricultural limestone value to irrigated fields in Southeast Missouri. Irrigators should soil test routinely to identify agricultural limestone needs.

Magnesium deficiencies are rare in the Midwest. However, magnesium is an essential plant nutrient that is present in Southeast Missouri irrigation water (Figure 5). As discussed with calcium, magnesium in combination with carbonate will represent some agricultural limestone equivalent. In general, magnesium concentrations in irrigation samples were one-tenth those of calcium. Still, if small areas in fields are magnesium-deficient, then irrigation will supply some magnesium crop needs.

Figure 5
Irrigation water magnesium concentration gradients (ppm) in southeast Missouri.

Iron and manganese were the only essential plant micro-nutrients present in sufficient quantities to benefit crops (Figure 6 and Table 1). However, deficiencies of these micro-nutrients are rarely reported in Southeast Missouri. Also, these nutrients commonly form precipitate minerals in water or soils. It is not expected that crop iron or manganese nutrition will be affected by levels in irrigation waters.

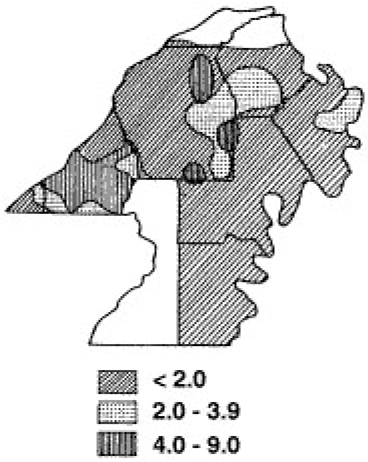

Figure 6
Irrigation water iron concentration gradients (ppm) in southeast Missouri.

Sodium is not an essential plant nutrient and usually is associated with detrimental effects on agricultural crop production. High sodium can be associated with poor soil structure and high salt content. If irrigation water contains large sodium concentrations, then degrading crop growth conditions may occur over time. However, sodium is very water-soluble and leaches readily through sandy soils. The area in a diagonal running northeast from southern Butler County to northeast Stoddard County contained appreciable amounts of sodium in irrigation waters (Figure 7). Irrigators in this region should consider the potential of long-term sodium build-up from irrigated cropland, especially on soils with low water infiltration and permeability.

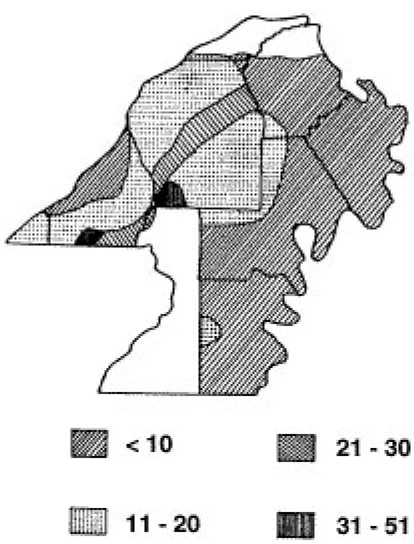

Figure 7
Irrigation water sodium concentration gradients (ppm) in southeast Missouri.

Irrigation water salt content should be a concern to all irrigators. Total salt content is correlated to electrical conductivity (E.C.) and measured in units of mmho per centimeter. Generally, irrigation water is considered excellent and low in terms of salt content when E.C. is less than 0.5 mmho per centimeter, and adequate when E.C. is below 1.0 mmho per centimeter. Although some irrigation water in Southeast Missouri (Pemiscot County and parts of Butler and Stoddard counties) contained E.C. measurements greater than 0.5, no well water in the region had E.C. measurements greater than 1.0 (Figure 8). Generally, irrigation water in Southeast Missouri applies small quantities of salts. On most soils, salt buildup as a result of irrigation should not be a problem.

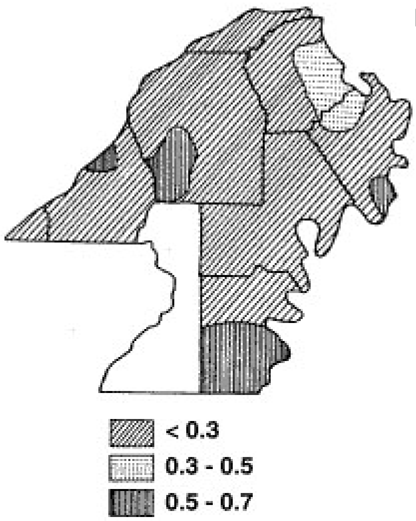

Figure 8
Irrigation water electrical conductivity gradients (m/cm) in southeast Missouri.

The survey results show that crop producers in Southeast Missouri are supplying some essential plant nutrients via irrigation water. This overlooked source of nutrients often should be considered when determining total fertilizer inputs. Well testing, combined with soil testing, can be an inexpensive means of evaluating nutrient budgets for crops grown in irrigated systems.

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