Making Manure Nutrient Management Work For You

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Crop nutrient management is not a new idea. In fact, the concept dates back quite a few years. The idea is being revisited by dairy producers for two key reasons. The first is economics. It costs money to purchase and apply nutrients (fertilizer) for crop needs. The second reason to revisit crop nutrient management is the potential contribution of manure nutrients to ground or surface water contamination.

It is important to realize that nutrient management assumes a few points. One area relates to the application of nutrients. It is assumed that nutrients are applied at the appropriate time with respect to growth and development of the plant. It is assumed that nutrients are applied in a form available to the plant. Some forms may be more readily available than others. It is assumed that the appropriate amount of nutrients is applied. The second category of assumptions deals with the location of the nutrients. It is assumed that the nutrients are applied where needed. It is assumed that the nutrients are not leached beneath the root zone of the plant. This last assumption requires consideration of irrigation water management.

The areas of manure nutrient management considered here include: how to sample manures, what to do with the laboratory results, consideration of irrigation uniformity and efficiency, and how to develop a farm nutrient management plan.

Sampling Liquids

Knowledge of your pond nutrient content is the first step in making liquid manure nutrients works for you. The nutrient content of water in a dairy pond depends on the number of animals contributing to the pond, the presence or absence of a solids separator, the amount of fresh water added daily, and the amount of manure collected from each animal.

There is no rule of thumb to account for the nutrients in manure waters. In fact, data from the western states indicate large variations in nutrient content of manure waters. Total nitrogen in an acre-inch of water was 28 lbs from one pond and 228 lbs. from another pond (Morse & Schwankl, 1995). A similar comparison from multiple ponds sampled in Idaho indicated average total nitrogen to be 83+60 lbs per acre-inch of water (Ohlensehlen et al., 1993).

It is critical to sample pond water to more closely estimate nutrient content. Sampling containers should be clean and dry. A sample should be more than a pint and less than a quart. Water should be flowing for at least 10 minutes before sampling. Fill the container about two-thirds full. Freeze the sample immediately after sampling. The empty air space in the container will allow the water to expand without breaking the container. Check with your analytical laboratory to determine the proper sample size, and particular handling practices for the sample. Labs may have sample containers for use.

It is easiest to sample water as it comes out of the pond and drops into the irrigation system standpipe. In fact, it is more precise to estimate nutrient content from manure water leaving the pond than it is to sample water in the pond. In some instances, it is not easy to access manure water as it enters a standpipe. If that's the case, sample manure water as it enters crop fields. When sampling at an irrigation valve (instead of a standpipe) it is important to let debris in the pipeline pass through, and to be sure the water being sampled is full strength manure water (not diluted).

Manure water should be analyzed from a pond during the spring dewatering. These waters can be different than waters used during the summer months. The results of samples taken on the same day are similar. Yet, results of samples taken on different days are quite different. At this time, the recommendation is to sample the manure water every other day during the spring dewatering. The average of the results should be used to estimate nutrient content of manure water.

Additional samples should be taken at least twice during the summer irrigations. If irrigation water is added to the pond, further sampling is recommended. This will improve the precision of estimating the nutrient content of the manure water. For instance, the nutrient content of the pond is reduced (diluted) when irrigation water is added.

It is more precise to estimate nutrient content from manure water as it comes out of the pond and drops into the irrigation system than it is to sample water in the pond.

Sampling Solids

The number of samples needed to estimate the nutrient content of solid manure depends on the amount and variability of the manure. Similar nutrient content of manures will come from animals of similar dietary nutrient intake. The nutrient content of manure from growing heifers, lactating cows and dry cows will differ. Also, the nutrient content of solids from a solid separator will be much different than the nutrient content of corral scraped manure. The important part of sampling is that the sample represent the source.

Using Laboratory Results

Often liquid samples are analyzed for total nitrogen, ammoniacal nitrogen, phosphorus, potassium, and salt (if a concern). All nutrients present are not readily available to plants. Phosphorus, potassium and salts are usually in a plant available form. Ammoniacal nitrogen (NH4-N) can be rapidly converted to nitrate (NO3) in the soil. Nitrate is the plant available form of nitrogen. In this sense, ammoniacal nitrogen is a fast release nitrogen and organic nitrogen is a slow release nitrogen source. The total remaining organic nitrogen can be converted to NO3 over time (usually years). Also, the NH4-N can be volatilized into air as ammonia. The percent volatilized depends on air and soil temperatures, soil conditions, amount of standing water, wind speed, and pH of the material. Few researchers are measuring the percent of nitrogen volatilized from land applied manure waters. It is assumed that 10% of NH4-N is volatilized during land application with a range between 5 and 25%.

Some elements on a lab report are reported in units of parts per million. Parts per million can be converted to pounds per acre-inch of water by multiplying the value by .2268. Elements expressed as percentages can be converted to pounds per acre-inch of water by multiplying the value by 2268.

Some nutrients (calcium, magnesium, sodium, chloride) may be expressed as milli-equivalents. These need special conversion factors. The laboratory supplying the analysis can assist you with appropriate conversions.

The next step is to calculate manure water flow. After that, it is a simple conversion to go from pounds per acre-inch of water to pounds per acre of field. Pumping rate of the manure water must be known.

Determining pumping rate is easier said than done. Usual farm pump tests seldom include checking manure pumps. One challenge of getting a manure pump test done is the fact that manure water isn't clean and therefore it dirties the individual attempting to install a metering device. Also, manure water has debris (straw, leftover feed, gloves, etc.) that will clog a typical propeller or turbine flow meter.

A non-invasive doppler meter can be used to measure flow rates. A sensor is strapped to the outside of the pipe and an ultrasonic signal is passed through the pipe. The signal is reflected by suspended particles in the fluid and the frequency shift in the signal is used to determine the velocity of the flowing liquid. Flow rate can then be calculated with the flow velocity and the pipe size. These meters are expensive, but may be owned by someone at the irrigation district, the electric company, or at your Cooperative Extension Office. Pump testing of manure ponds should be done when the pond is at various depths as the depth of water in the pond alters the pumping rate.

It's easy to calculate nutrient flow after the sample results are received from the lab and the pump test results are known. The calculation is as follows:

nutrients applied	= nutrient content	X water applied
(lbs applied)	(lbs/ac-in)	(acre-inches)

Water applied can be calculated by multiplying the flow rate (gallons/minute) by the amount of time the water flowed (number of minutes) divided by 27,154 gallons per acre-inch of water. For a pump that discharges 300 gallons/minute the calculation for 2 hours (120 minutes) is 300 X 120/27154 = 1.3 acre-inches. The nutrients entering the field are divided by the amount of acres to determine the pounds of nutrients applied per acre of cropland.

An example of nutrients (pounds) applied to a field during a one-hour irrigation are in Table 1. After 1 hour of pumping with a 100 gallons per minute pump, and a nutrient content of 100 parts per million, 5 pounds of the nutrient entered the field. If the pump rate was 500 gallons per minute and the nutrient content was 100 parts per million, then 25 lbs of nutrients would enter the field. Note: these calculations are for a pump working 1 hour. Most irrigations are more than 1 hour.

Results from solid manure samples are similar to forage test results. Moisture and percentages of each element will be listed. Total nitrogen will be reported. Unless requested, ammoniacal nitrogen will not be reported. A useful calculation is to determine the amount of nutrient applied per ton of wet manure applied.

Table 1. Amount of nutrients applied to a field (pounds) based on nutrient content of water (parts per million-ppm) and pump rate (gallons per minute-gpm). This assumes the pump ran for 1 hour.

nutrient content (ppm)	100 gpm	300 gpm	500 gpm
25	1	4	6
50	3	8	13
100	5	15	25
150	8	22	38
200	10	30	50
250	13	38	63
300	15	45	75

Irrigation Efficiency And Uniformity

Once nutrient content (lab analysis) and application rate (pumping rate for liquids, spreading rate for solids) are known, the next step is to determine where nutrients are going. Nutrients in manure water follow the water flow. Although a considerable amount of solids can settle out during an irrigation, nutrients don't settle out (Morse et al., 1994).

It is important to identify how much and where water goes during an irrigation. Irrigation water applied to a field can end up in one of three locations. The desired location is for water to be stored in the crop's root zone. Storing water in the crop's root zone is the normal objective of an irrigation. Irrigation water can run off from the field surface. Tail water return systems can be used to capture surface runoff and reuse it. Other surface runoff is illegal in California. Another location where water may end up is below the crop's root zone. Excess water results in deep percolation. Both water and nutrients move beneath the crop's root zone. Nitrate is very mobile in soil and moves with the deep percolating water front. These losses are undesirable as more water is used than needed and leached nutrients may contaminate groundwater.

Irrigation efficiency describes how much of the applied irrigation water is stored in the crop's root zone. This number expresses the amount of water used by the plant as a percent of the water applied. The formal definition of irrigation efficiency (IE) is:

$$\text{Irrigation Efficiency (IE-\%)} = \frac{\text{water beneficially used X 100}}{\text{water applied}}$$

Beneficially used water is the amount of water needed to refill the crop's root zone. This amount of water is equal to the soil moisture used by the crop since the last irrigation. Irrigation scheduling techniques can be used to determine the irrigation amount required. These techniques include determining plant evapotranspiration (ET) and/or soil moisture monitoring. For instance, if the last irrigation was 10 days ago, ET estimates may indicate that the crop used 2.5 inches of water (0.25 inches/day x 10 days = 2.5 inches). The objective of irrigating would be to apply 2.5 inches of water to refill the crop's root zone.

Irrigation Application Uniformity

Water application uniformity describes how evenly water is applied to the field. If every part of the field received the same amount of irrigation water, the irrigation would be 100% uniform.

Distribution uniformity (DU) is commonly used to quantify uniformity in furrow and border irrigation systems. It is defined as:

$$\text{distribution uniformity (DU-\%)} = \frac{\text{depth of water applied to low } 1/4 \text{ of field X 100}}{\text{average depth applied}}$$

The depth of water applied to the low 1/4 of the field is the depth of water applied to the 25% of the field which receives the least water. For furrow-irrigated fields, this is usually the 25% of the area at the tail end of the field.

Irrigation water application rate should be determined. Measuring manure water quantities was discussed previously. The contribution of clean irrigation water can be determined. Pump test results from a well can be used to estimate flow rates. Realize these estimates can lead to errors as changes in pump performance, pumping depth, etc. can change pump rate. A more precise method of determining well wat~~er flow rate is to use an in-line meter~~ (e.g. propeller meter). Additionally, flow rate should be determined for canal water.

Interactions Between Irrigation Efficiency And Uniformity

Understanding the relationship between irrigation efficiency and uniformity is the key to understanding good irrigation water management. It is not possible to adequately irrigate a field efficiently (the appropriate amount of water) unless the water is applied uniformly. However, irrigating uniformly will not guarantee that the irrigation is efficient.

Efficiency - How much of the applied irrigation water goes to the crop.

Uniformity- How evenly irrigation water is applied to the field.	Good	Poor
Good	**Desired** **Minimal hazard to groundwater.**	● Practice irrigation scheduling to prevent over-irrigation of the crop. ● Measure irrigation flow rates. ● Use tailwater return system to reduce tailwater runoff problems.
Poor	● Under-irrigation - practice irrigation scheduling. ● Use higher irrigation flow rates to the field. ● Reduce or eliminate deep soil ripping. ● Use tailwater return to ensure adequate irrigation of the entire field. ● *Consider shortening the field to improve the irrigation uniformity.*	● Over-irrigation - practice irrigation scheduling. ● Measure irrigation flow rates. ● Use tailwater return system to reduce tailwater runoff problems. ● Consider shortening the field to improve irrigation uniformity. ● Use higher irrigation flow rates to the field, but need to adjust irrigation set time in accordance. ● Use furrow torpedoes for early irrigations. ● Reduce or eliminate deep soil ripping. ● Consider use of surge irrigation. ● Increase the field slope to increase the irrigation water advance rate.

Fig. 1. Management practices to improve irrigation efficiency and uniformity.

Potential of contaminating groundwater by deep percolation from manure water irrigations will be affected by:

(1) the irrigation water nutrient concentration;

(2) the chemical form of nitrogen in the irrigation water;

(3) soil characteristics such as permeability, porosity, and texture; and

(4) soil nutrient levels prior to irrigating. Information is not available currently to predict the nutrient content of deep percolating water resulting from a single irrigation event.

Management Measures To Improve Irrigation Practices

The following scenarios illustrate the combinations of irrigation efficiency and uniformity. Management alternatives are provided to reduce the risk of contaminating groundwater. Each of these scenarios has a potential impact on groundwater quality. The extent of contamination will depend on the amount of deep percolation and the nutrient content (e.g. nitrate). The fourth combination – good efficiency and good uniformity – is the desired irrigation event. A summary of management alternatives to minimize groundwater contamination is in Figure 1 on the preceding page.

Irrigation Uniform But Inefficient

Scenario 1 is an irrigation which is uniformly applied, but is inefficient. In this case, the irrigation system is performing acceptably. Water is uniformly distributed. However, water is not used efficiently. Irrigation scheduling is not being practiced and/or water quantity is not being measured. Excess irrigation water is being applied. Over applied water will result in deep percolation. Both soil and manure water nutrients can move downward with the deep percolating irrigation water.

Irrigation efficiency can be improved to decrease the amount of deep percolation. One method to improve efficiency is to decrease the amount of water used in an irrigation. Another method is to increase the interval between irrigations. Either alternative should more closely match the soil moisture used since the previous irrigation. Usually, it is more practical to increase the interval between irrigations. Frequently a minimum amount of water must be applied for the water to advance across the field. An alternative management technique may be to match the minimum water application amount with the corresponding irrigation interval. Crop water use would be equivalent to the irrigation amount needed to advance water across the field.

A fourth alternative to improve irrigation efficiency is to collect and reuse tail water runoff from the field. Tail water return systems allow use of large flow rates and can help ensure that the tail of the field is adequately irrigated. The adoption of irrigation techniques to avoid tail water runoff – small flow rates, long field lengths, etc. – can lead to inefficient and non-uniform irrigations. Substantial deep percolation at the head of the field is a common result, and inadequate irrigation at the tail of the field is also common.

Irrigation Efficient But Non-Uniform

Scenario 2 is an irrigation which is efficient but non-uniform. On the average, the correct amount of water is applied to the field (it's efficient). For example, if 3 inches of water have been depleted from the soil profile by crop water use, for each acre irrigated, 3 acre-inches of water would need to be applied. For furrow irrigation, the non-uniformity usually results in the head of the field being over-irrigated while the tail of the field is under-irrigated. The over-irrigation (inefficient) at the head of the field would produce deep percolation. The deep percolation could move soil and manure water nutrients into underlying groundwater. Thus, even though on the average the correct amount of water was applied, the application non-uniformity would result in deep percolation. The irrigation system application uniformity must be improved in order to adequately irrigate the entire field while irrigating efficiently. Alternative practices to improve uniformity are included in the next section.

Irrigation Inefficient And Non-uniform

Scenario 3 is an irrigation which is inefficient and non-uniform. Such an irrigation results from excess use and uneven distribution of water. This scenario holds the greatest potential for deep percolation and contamination of underlying groundwater.

This scenario occurs when the field length is too long to irrigate uniformly. Also, irrigations on soils *with poor water holding capacity are often inefficient and non-uniform. Only a small amount of water per irrigation is needed to refill the crop's root zone. Such conditions exist when sandy soils are irrigated. Such soils don't store much water and need small yet frequent irrigations.*

The major criterion for determining irrigation set time is the amount of time it takes to get water to the end of the field (advance time). The minimum depth of water which can be applied per irrigation is controlled by the end-of-field advance time. For example, if corn irrigations are at 10-day intervals, the irrigation objective may be to apply 3 inches of water during the irrigation. This objective would result in an efficient irrigation. The length of the field requires application of a minimum of 5 inches of irrigation water simply to advance water to the end of the field. The result is an irrigation event which is inefficient (over-irrigated).

Irrigation non-uniformity is a result of the different lengths of time water is in contact with the soil (infiltration time) at various parts of the field. For example, a typical, 800-foot, furrow-irrigated field may require 8 hours to advance water to the end of the field. The irrigation water is shut off when it reaches the end of the field. Water therefore infiltrates for 8 hours at the head of the field and for only a few minutes at the tail of the field. This difference in infiltration time results in significantly more water soaking into the soil at the head of the field than at the tail of the field. Irrigation non-uniformity is the result of such an irrigation.

Furrow and border irrigation often suffer from such an irrigation non-uniformity problem. There will always be a difference in infiltration time between the head and tail of the field resulting from the time it takes to advance water across the field. Shorter field lengths have lesser infiltration time differences between the head and tail of the field. This results in better irrigation uniformity.

Alternative management practices can improve the irrigation system's application uniformity. Physical changes require capital expenditures. The costs and benefits (water and nutrient conservation) need to be evaluated for each alternative. The following alternative practices may be used to improve application uniformity.

- *Change the field slope. Increasing the slope of a field will cause water to advance across the field more quickly. This will reduce the time water is allowed to infiltrate at various field locations.*
- *Increase the water flow rate to the field. This will result in faster water advance across the field and reduce the time water is allowed to infiltrate.*
- *Reduce deep ripping of the field or alter season of deep ripping. Deep ripping prior to field preparation and irrigation results in an increased infiltration rate and a slower water advance time down the field. The slower water advance results in greater irrigation non-uniformity. Eliminating deep ripping altogether or minimizing its use can reduce the severe irrigation non-uniformity problems often experienced during the pre-irrigation and early season irrigation events. There is no capital cost associated with reduced deep soil ripping.*
- *Use furrow torpedoes. Furrow torpedoes are weighted steel cylinders, 6 to 12 inches in diameter and up to 4 feet long. Torpedoes are dragged in furrows to break up soil clods and smooth the furrow surface. They are most effective when used prior to the pre-irrigation or following field cultivation. The result is more rapid irrigation water advance and improved irrigation uniformity.*
- *Use surge irrigation. Surge irrigation is turning water on and off as it flows down the field. Water is allowed to flow down the field for a given distance. The flow is stopped until the water in the furrow recedes. The water flow is restarted. This can result in less water being used to advance the irrigation water to the end of the field. During the off-time, the flow can be diverted to other parts of the field. The second water surge wets both the previously wetted length of the furrow and an additional section of dry soil. This procedure continues until water reaches the end of the field. Use of surge irrigation can improve the irrigation application uniformity as well as the irrigation efficiency. While surge irrigation can be done manually, automation requires a surge valve and gated pipe.*

• Reduce the field length. This is the most effective step which can be taken to improve irrigation uniformity, but it is also very expensive. The costs, such as new supply pipeline and re-leveling, can make reducing field lengths impractical.

Nutrient Management Program

Two final pieces of information are needed before a nutrient management plan can be developed. Soil nutrient content and estimated plant nutrient use should be known. The number of soil cores needed to determine soil nutrients depends on field variability. Contact the local Cooperative Extension Office or Natural Resource Conservation Service (formerly the SCS) for advise on soil sampling. They can also aid you in determining the depth of the sampling. Certainly, one needs to sample through the depth of the crop root zone. You may chose to have soil samples taken by a private lab.

Plant nutrient use can be determined in one of two ways. One method is to determine the amount of nutrients harvested the previous cropping season. This is easy to do when a forage crop was grown and harvested. Yields and nutrient content would be available. Another method is to use recommended nutrient requirements for crops where all the plant matter isn't harvested, or it is harvested but not analyzed for nutrients. Nutrient needs of cotton or cereal grains are best determined from local data or standard tables for your county or state.

Now actual nutrient management plan can be developed. For each field, the following calculations should be made. Amounts of nitrogen, phosphorus and potassium needed by the plant and present in the soil should be estimated. By difference, the approximate amount to apply is calculated. The actual amount of nutrients supplemented may be more than what is calculated. This would allow for nitrogen lost to the atmosphere that is not available to the plant.

	Tons	N	P (lbs/acre)	K
1. Est. crop yield	_____	___	___	___
2. Avail soil nutrient contribution		___	___	___
3. Add'l nutrients needed (line minus line 2)		___	___	___

If line 3 is greater than 0, then the land can accept manure nutrients. Other items to consider in a nutrient management plan include when to apply nutrients, soil nutrient and water holding capacity, and soil type.

Realize that if manure nutrients are applied to meet the nitrogen needs of a crop, phosphorus, potassium and salts are usually over applied. This can lead to an undesirable buildup of salts in the soil. Although deep percolation is a standard practice to remove excess salts from the crop root zone it will result in salts leaching into the underlying groundwater. Also, phosphorus is not easily leached through the soil, but can be a concern related to surface water quality. Phosphorus enters surface waters when soil is eroded.

Additional nutrients needed can be obtained through a variety of sources: irrigation water, manure water, solid manure, other soil amendments or commercial fertilizer. The application rate of manure nutrients should depend on the nutrients needed. the soil nutrient needs should be used to determine if the land can accept manure nutrients and at what rate the nutrients can be applied. Once this is calculated, then the manure application rate is determined.

The limiting nutrient to determine manure application rate will vary. If surface water concerns exist, phosphorus usually limits application rate. If groundwater concerns exist, nitrogen or salts may determine application rate.

Producers who live on poor soils and have high water tables must be particularly careful with nutrient applications. Such locations are more susceptible to groundwater contamination. Excessive irrigation water use can be detrimental. Both nutrient management and water use must be managed to prevent contamination of groundwater.

The biggest question arises when nutrient management plans are developed and it is evident that insufficient land exists to utilize manure nutrients. When this occurs there are other alternatives. The *appropriate combination of alternatives will depend on the magnitude of the extra nutrients and which nutrients are excessive.*

A successful nutrient management plan will monitor nutrients applied to soil as well as nutrient movement through the soil. Irrigation water management is a critical element to nutrient movement in the soil.

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notes