CONSIDERATIONS FOR SWITCHING FROM FLOOD TO MANURE SUBSURFACE DRIP IRRIGATION FOR FORAGE PRODUCTION

Prepared by Sustainable Conservation

Abstract

Installation of a manure subsurface drip irrigation (manure SDI) system for growing forage on a conventional flush dairy requires modifications to equipment and infrastructure. While the equipment needed are off-the-shelf parts, successful operation requires to farm and manure management, including additional training for operating the manure SDI's computer system. The following considerations are based on lessons learned from constructing and operating the manure SDI system at three dairies in the San Joaquin Valley.

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Contents

1.0 Deciding on Suitability for the Dairy

1.1 Whole Farm Nitrogen Balance

An analysis of the nitrogen mass balance of the dairy is an important first step before deciding to switch from flood to manure SDI. The manure subsurface drip irrigation (manure SDI) system more efficiently applies water and nutrients to crops than flood irrigation systems, meaning less water and manure effluent need to be applied to grow forage crops. Therefore, the use of the more efficient manure SDI system will not help dairies address a manure nitrogen surplus.

Dairies with excess manure nitrogen should first determine how to get into nitrogen balance, with options such as a manure export plan. A comprehensive nutrient management plan (CNMP) will help evaluate the situation. For additional information about evaluating the whole farm balance and manure nutrient export strategies, talk with an agronomic consultant.

1.2 Management Considerations

Adoption of the manure SDI system has a learning curve and will take adaptation by the dairy. The manure SDI system can be adopted by dairies producing their own forage crops with their own staff. Dairy producers that contract out silage production will need to discuss with their custom farming partners about the custom farmer's ability to operate and manage the technology. In both scenarios, management of the manure SDI system is substantially different from flood irrigation. For additional guidance, please review the separate technical report, "Nutrient and Salinity Management Guidance for Manure Subsurface Drip Irrigation Systems."

1.3 Long-term Irrigation Strategy

Producers testing the manure SDI system typically start with one or two fields. During the testing phase, operating both flood irrigation and manure SDI system is very helpful in learning about the system, but long term is a less efficient use of irrigation labor and management. In order to increase labor and agronomic efficiencies, consider developing a strategy for transitioning the entire forage production acreage from flood to manure SDI in a phased approach and make design and operational decisions based on that strategy.

1.4 Installation Cost

A cost analysis was developed to compare the manure SDI system with a conventional SDI system that uses synthetic fertilizer in the separate technical report, "Cost Analysis of Manure Subsurface Drip System on California Dairies." Results indicate that the costs to purchase and install the automated manure SDI system is about $3,424 per acre as compared to $2,683 per acre for an equivalent automated conventional SDI system or $2,254 per acre for a non-automated conventional SDI system. The difference in costs is driven primarily by automation, additional pumps and pipelines needed to get the manure effluent into the system, and the need of doubling the capacity of sand media filters compared to SDI systems not using manure.

1.5 Financial Assistance Programs Available

1.5.1 Environmental Quality Incentives Program (EQIP)

Cost share funding for manure SDI is available through the EQIP program; talk with the local NRCS office to ask for details. As of November 2019, the NRCS offered a $2,871.93 per acre cost share for producers interested in installing the manure SDI system in California. The initial cost-share per acre rate may eventually decrease. Cost share funding is also available for manure separation systems. In order to apply for EQIP, the NRCS requires that producers complete a CNMP. The objective of a CNMP is to document a dairy's plan to manage water, manure, and organic by-products by combining conservation practices and management activities into a conservation system.

1.5.2 Alternative Manure Management Program (AMMP)

The California Department of Food and Agriculture (CDFA) offers the Alternative Manure Management Program (AMMP) funding which periodically provides financial assistance for the implementation of non-digester manure management practices in California, which will result in reduced methane emissions. AMMP funding will be of value if manure separation upgrades are needed. AMMP, however, will not fund manure SDI. Check for updates at https://www.cdfa.ca.gov/oefi/AMMP/

1.5.3 State Water Efficiency and Enhancement Program (SWEEP)

CDFA also offers the State Water Efficiency and Enhancement Program (SWEEP), which periodically provides financial assistance in the form of grants to implement irrigation systems that reduce greenhouse gases and save water on California agricultural operations. Eligible system components include (among others) soil moisture monitoring, drip systems, switching to low pressure irrigation systems, pump retrofits, variable frequency drives and installation of renewable energy to reduce on-farm water use and energy. The manure SDI system is eligible for funding and the most recent round of funding covered up to $100,000 of installation costs. Available funding and requirements can change, so check for updates at https://www.cdfa.ca.gov/oefi/sweep/

2.0 Setting up the Manure SDI System

2.1 Personnel

Consider the following operational roles needed to run the manure SDI system and how they can be integrated into the existing operation.

2.1.1 Technical Lead

When the system is installed, the dealer will train a group of dairy employee. Training will include management of critical components like:

- The irrigation controller which manages irrigation scheduling
- The variable frequency drive: optimizes pump efficiency

Operating the manure SDI system will involve understanding how to program the settings for the various irrigation functions, basic troubleshooting, and how the EC sensor works with the butterfly valve to adjust the fresh water to manure effluent ratio. The team should designate a technical lead for programming the manure SDI system. Ideally, the lead will also be the main point of contact with the equipment provider.

2.1.2 Agronomic Consultant

The farm personnel will need to coordinate with a knowledgeable agronomic professional to adjust system settings to meet irrigation and nutrient requirements. A suitable professional might be a Pest Control Advisor (PCA), a Certified Crop Advisor (CCA) or a Technical Service Provider (TSP).

With the agronomic professional, the dairy's team will need to establish the appropriate sampling and testing protocols for gathering the data needed to adjust the system settings to meet crop demand. Some suggestions for considerations can be found in the separate technical report, "Nutrient and Salinity Management Guidance for Manure Subsurface Drip Irrigation Systems."

2.1.3 Irrigator

The manure SDI system is designed with automation features intended to make operation of the system more efficient. These automation features may require additional irrigator training. The irrigators should be able to read and understand the instructions and manage a computer module for irrigation scheduling.

While many of the manual tasks associated with flood irrigation will no longer be needed, the irrigator will have to take on new roles, including:

1. Starting and shutting down the system based on outlined procedures. (Easy-to-use operator switches are available).
2. Adjusting manure effluent and irrigation blend to meet crop evapotranspiration (ETc), nutrient requirements, and system capacity.
3. Maintain system operation within required performance specifications, such as adjusting the settings to account for changes in manure effluent concentration and backflush frequency.
4. Operating chemical injection system.
5. Manually flushing the drip tape periodically.

6. Inspecting and repairing or replacing drip tape and emitters as needed.
7. Updating irrigation logs to record system start and stop times, maintenance activities, manure effluent blend ratios, and flow meter readings.

2.2 System Design

2.2.1 Components

None of the manure SDI hardware components were custom-made, so they are readily available. They are engineered together handle manure effluent blended with fresh water as a nutrient source. The main components are:

- A fresh water pump, controlled by a variable frequency drive
- A manure effluent pump, controlled by a variable frequency drive
- Sand media filters
- An EC sensor
- An automatically adjusting butterfly valve that controls manure effluent
- A chemical injection system
- An automated irrigation scheduling controller

Filters are designed with double the capacity of an equivalent conventional SDI system. The backflush from the sand media filters should return captured sediments back to the lagoon or tail water return ditch.

The field components for manure SDI systems are identical to conventional SDI systems. Spacing for silage corn on drip is typically 30 inches between laterals on most soils; however, to allow for smooth transition between corn, wheat, and alfalfa, a 40 inch spacing is recommended instead. A 40 inch lateral spacing is also ideal with the use of twin-row planters; the setup is also compatible with one-row planters.

2.2.2 Sizing and Capacity

The sizing and capacity of the manure SDI system is primarily dependent on

- Acreage to be irrigated
- Distance between field and the manure SDI system
- Maximum concentration of suspended solids in manure effluent.

The pumps and filters need the capacity to deliver water and nutrients to the root zone at rates that satisfy crop requirements during the entire phase of vegetative and reproductive growth. As distance to the field increases, system efficiency decreases. System efficiency is also reduced if the automated backflush system is initiated too often in response to clogged filters. Pumps and filters need to be sized to handle the maximum expected concentration of suspended solids to keep backflush intervals within acceptable limits.

2.2.3 Retrofitting Conventional SDI to Manure SDI

Conventional SDI systems can potentially be converted to manure SDI. Conventional SDI systems designed for row crops or alfalfa use synthetic nutrients. In addition to the factors described above, conversion to manure SDI will also depend on reliable access to manure effluent. The choice of emitters, spacing of drip tape and pump capacity of each conventional or manure SDI system is designed to achieve a delivery rate specific for each crop and soil type. The entire delivery system will need to be reviewed when considering retrofits to use manure effluent as a nutrient source.

2.2.4 Field Selection for Initial Installation and Expansion

Initial design of the manure SDI system should take into consideration long term crop production and farm management objectives. For example, the initial pump and filtration capacity can be designed for multiple fields even when the first phase of installation is limited to one field.

Fields should also be selected with a crop rotation plan in mind. For example, an existing corn and winter forage rotation field may eventually be planted to alfalfa for four to six years. In that scenario, design the manure SDI system with all three crops in mind.

Rectangular fields allow a more cost effective design of manifolds, sub-mains and laterals. Irregularly shaped fields will require higher material and installation expenses per acre.

2.3 Water Sources

If using groundwater, sample the water for nitrogen, salts, and solids content. The nitrogen tests are for the nutrient management plan, which should consider nitrogen from all sources. Under some circumstances, fine sand pumped from groundwater wells may degrade the performance of sand media filters, hence testing the solids content.

2.4 Manure Management System

In preparation for installing the manure SDI system, a review of the dairy's manure management system is recommended. Flood irrigation systems on dairies can generally tolerate substantial amounts of coarse manure solids and still apply the fresh water and manure effluent blend to the fields. To convert to manure SDI, retrofits to the manure management system may be needed to reduce the concentration of coarse solids.

2.4.1 Primary Lagoon

Evaluate whether the dairy needs to increase the removal of coarse solids in the primary lagoon. For example, adding settling ponds, weeping walls, slope screen separators or other infrastructure. Also review management of the primary lagoon and the balance of manure effluent and fresh water. Lagoon loading of manure and fresh water should be balanced in order to ensure a steady flow of manure effluent to secondary or tertiary ponds for use by the manure SDI system.

2.4.2 Secondary or Tertiary Lagoon

The manure SDI system requires inflows of nutrient rich manure effluent with stable and relatively low concentration of suspended solids. As the suspended solids load is reduced, the manure SDI system becomes more energy efficient and cost effective in delivering water and nutrients to meet crop requirements.

Therefore, it’s recommended to source the manure effluent from a secondary or tertiary pond. Manure effluent from a secondary or tertiary pond is preferred because they tend to be more consistent and have fewer coarse solids as compared to a primary lagoon.

Evaluate the concentration of suspended solids currently pumped from the secondary or tertiary lagoon that will support the manure SDI system. If suspended solids are minimal, then it’s likely that no additional steps are needed. If suspended solid concentrations are relatively high, then consider practical steps that could reduce the load of suspended solids from the lagoon prior to intake by the manure SDI system. One option is additional fine solids separation between the pond and the manure SDI system. The types of fine solids separation may include slope or rolling screen separators with finer screen mesh sizes to capture more solids. Many alternatives for finer separation of fine solids are available to suit specific needs and budgets.

2.4.3 Manure Pipelines Configuration

It is highly recommended that the manure SDI system be connected directly to the secondary or tertiary pond via a dedicated pipeline instead of sharing a pipeline with a flood irrigation system. The sharing a pipeline could limit the volume and timing of manure effluent, making it difficult to efficiently operate both manure SDI and flood irrigation systems in tandem.

Pressurized pipelines allow better control over delivery of manure effluent. Although it is preferable to locate the pump and filter pad closer to the lagoon, it is possible to locate the pumps at sites far away from the lagoon to grant greater flexibility and fit with the dairy's long term crop production strategy.

2.4.4 Dairies with Anaerobic Digester Systems

Digestate from anaerobic digesters can be used with the manure SDI system. The nutrient composition and other characteristics of digestate vary considerably from manure effluent. When used as a nutrient source, it is important to evaluate the effects of digestate on plant development and to adjust management practices as necessary.

2.5 Field Tillage Techniques

When transitioning to manure SDI for row crops, growers have successfully used a variety of land preparation tools. Evaluate the existing tillage practices and equipment requirements; modify them to work with buried drip tape as needed. The key is that any tool used cannot interfere or damage with the drip tape. Precision GPS guidance techniques are needed for tillage and planting in order to avoid damage to the drip tape while also placing seeds the proper distance from the tape.

2.6 Maintain Flood Irrigation System

When switching from flood to manure SDI, maintain your existing flood irrigation system. Each system can complement the other. A flood irrigation system is an effective method for flushing of salts and controlling gophers. Germination using the drip tape has not proven effective with the manure SDI system and flood irrigation also allows you to pre-irrigate to provide moisture for germination. If using flood, the field must be levelled prior to the installation of the field components (i.e. mainlines, drip tape, flush manifolds), so that flood irrigation water can be evenly distributed without ponding.

3.0 Operating the Manure SDI System

3.1 Irrigation Management

3.1.1 Germinating Corn

Producers have experienced poor results using the drip tape to germinate corn. The drip tape is typically buried eight to twelve inches in the ground, so the first few inches of the soil surface can remain dry during the first irrigations. The preferred methods to start the seedlings are sprinklers or pre-irrigation with flood. The manure SDI system is then used when the seedling roots are developed enough to access deeper soil moisture.

3.1.2 Winter Irrigation

Winter forage nitrogen requirements should also be carefully monitored during wet winters, as less irrigation is needed when fields are wet. If the manure SDI system is infrequently used during the winter, manure effluent nutrients may be inadequate to meet crop demand. If needed, the manure SDI system can apply synthetic fertilizer through the drip tape to provide nitrogen to meet the crop's nutrient requirement with minimal over application of irrigation water.

3.2 Soil Types and Management

3.2.1 Prioritize Sandy and Heavy Clay Soil Textures

When evaluating fields for manure SDI, soil texture is an important criteria. The manure SDI system improves water use efficiency by providing a stable and consistent supply of water to the root zone. This is particularly beneficial in both very sandy and heavy clay soils.

Sandy soils tend to have a low water holding capacity and are typically difficult to flood irrigate. Sandy soils also readily leach both water and nutrients below the root zone. The manure SDI system can be configured to apply water and nutrients at rates that more closely match plant uptake, limiting leaching in sandy soils.

Heavier soils with high clay content have a relatively high water holding capacity, but plant available water can be limited because it is tightly held in the soil pores. Heavier soils therefore tend to be poorly drained and require smaller and more frequent irrigation events, which manure SDI is well suited for. So, fields with very sandy or heavy clay soils would both benefit from manure SDI systems.

3.3 Nutrient Management

A nutrient management plan is the most effective method for determining nutrient application rates. Nutrient planning and close monitoring throughout the cropping season is critical with manure SDI systems because of relatively low delivery rates. Nitrogen budgeting is important especially when relying on manure as a primary nutrient source because the organic nitrogen in manure is initially unavailable and slowly released over time. Providing adequate nutrients to meet early stage development is critical to determination of eventual yield.

3.3.1 Balancing Plant Water and Nutrient Demand is Critical

The manure SDI system has to achieve multiple objectives: meet the crop ETc, apply nutrients at sustainable rates for plant growth. The most important periods are peak ETc and nitrogen demand prior to and during tasseling for corn. If nutrient application rates do not keep up with crop demand during critical periods, the manure SDI system may not be able to catch up and it may be necessary to resort to application of synthetic nutrients.

A practical approach to tracking manure nitrogen and crop ET requirement was developed by a dairy partner with experience operating and evaluating the manure SDI system. The tracking sheet (Table 1) can be adapted to the unique needs of each dairy.

3.3.2 Sampling Protocols and Sample Results

Delays in getting sample results can affect the ability to make or modify nutrient recommendations. It is also important to keep track of crop nutrient requirements throughout the entire season. The tracking of nitrogen content through the use of frequent lab testing may not be ideal for every dairy operation, so each dairy should work with their agronomic consultant to determine an appropriate approach.

3.3.3 Dry Manure Spreading

Each grower should refer to the dairy's nutrient management plan and work with an agronomic consultant on whether to add solid manure and how much to add.

3.3.4 Salinity Management

When manure effluent is applied via drip tape, salt concentrations may increase around the wetting zone. Conduct periodic salinity testing within one to three feet deep and lateral to the manure SDI drip tape. Flush the field based on soil testing and as recommended by the agronomic consultant. For further details, please refer to the separate technical report "Nutrient and Salinity Management Guidance for Manure Subsurface Drip Irrigation Systems."

Table 1. Irrigation and nitrogen application tracking worksheet developed by one of the producer partners.

Manure SDI Irrigation Schedule Field:												
Week	**Dates**		**ET** (inches/day)	**cKo**	**Inches per week**	**Hours**	**Number of sets**	**Hours of Runtime** (actual)	**% total N**	**# N need / week**	**inches / acre lagoon**	**Blend Ratio**
25	19-Jun	25-Jun	0.3	0.5	1.13	66	4		2%	6	0.13	12%
26	26-Jun	2-Jul	0.31	0.5	1.17	69	4		5%	15	0.33	28%
27	3-Jul	9-Jul	0.32	0.6	1.45	85	4		5%	15	0.33	23%
28	10-Jul	16-Jul	0.32	0.7	1.69	99	4		8%	24	0.52	31%
29	17-Jul	23-Jul	0.31	0.8	1.87	110	4		10%	29	0.65	35%
30	24-Jul	30-Jul	0.31	0.9	2.10	124	4		10%	29	0.65	31%
31	31-Jul	6-Aug	0.3	1	2.26	133	4		15%	44	0.98	43%
32	7-Aug	13-Aug	0.285	1	2.15	126	4		15%	44	0.98	46%
33	14-Aug	20-Aug	0.27	1	2.03	120	4		10%	29	0.65	32%
34	21-Aug	27-Aug	0.26	1	1.96	115	4		8%	24	0.52	27%
35	28-Aug	3-Sep	0.25	1	1.88	111	4		8%	24	0.52	28%
36	4-Sep	10-Sep	0.23	1	1.73	102	4		4%	12	0.26	15%
37	11-Sep	17-Sep	0.22	1	1.66	97	4		4%	12	0.26	16%
38	18-Sep	24-Sep	0.2	1	1.51	89	4		0%	0	0.00	0%
39	25-Sep	1-Oct	0.18	1	1.35	80	4		0%	0	0.00	0%
40	2-Oct	8-Oct	0.15									
41	9-Oct	15-Oct	0.15									
42	16-Oct	22-Oct	0.12									
43	23-Oct	29-Oct	0.12									
44	30-Oct	5-Nov	0.1									
								Total	104%	306	6.80	24%
			#NO3/acre-inch									
		Lagoon water	45									
		Yield Goal	32									
		N Removal/ton	9.2									
		Total # N/acre	294									
Total acre-inches/acre lagoon			6.54									