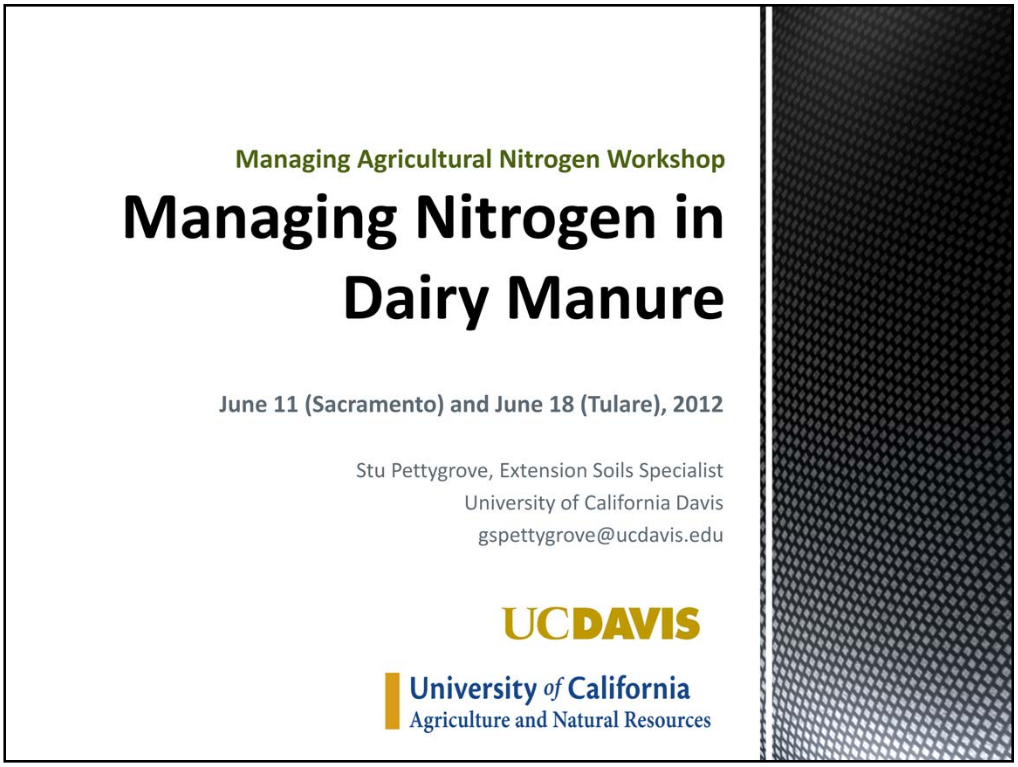


Organic N sources in the Central Valley mostly means dairy cows, which excrete as manure an amount of N approximately equal to 40% of the synthetic fertilizer N in the entire state. To consider how to manage this, we cannot start with the idea the it is just another fertilizer material.

While it contains essential plant nutrients, especially NPK, it is not a fertilizer but rather a waste; and it must be collected, treated and to some degree transported away from the source farms in order to be recycled. So.. Three questions:

What are the key features of the system that generates this waste?

What are the weak points of the system that lead to N imbalance and ultimately contamination of GW with nitrate?

What are the highest priority R&D needs for addressing this problem?

The first key feature is tremendous complexity of these operations, with the production of a highly perishable product 2X/day, 365 days/yr, unforgiving requirements for product sanitation and animal care, and the need to integrate animal husbandry, product quality control, waste management, irrigated feed production and processing. Weak links in this complicated system on many dairies are: surface irrigation systems, waste management system, which produces several distinct types of heterogeneous wastes – not just “corral manure” and “lagoon water”, and low tech and poorly engineered waste systems, e.g. lagoons that do not produce a homogeneous wastewater for application to fields.

The second key feature and one more specifically related to the problem of nitrogen imbalance, is that the N-throughput, defined as lb of N applied per acre of land per year is the highest of any farming system in the world, typically 400-600 lb N/acre – perhaps double the throughput of most cropping systems. Even if only 20% of this were leached past the rootzone – something that will be impractical to achieve on the most permeable soils-- this would amount to around 100 lb N/acre – which is more than enough to significantly degrade groundwater for potable use. There have not been very many studies in California of dairy forage crop N balances. I will show you one example.

UC dairy crop field N balance study

2007-2008 San Joaquin Valley

	Soil, %sand	Crops (C=corn, O=oats)	Total N applied	N harvested in crop	NO_3-N leached below 6 ft*
			-------------------- *lb N/acre*	-------------------	
Farm 1	80	C-sudangr-triticale-C	1484	821	528
Farm 2	69	C-O-C	1441	678	347
Farm 3	67	C-O-C	714	541	132

*Simulated with RZWQM model

-- from Geisseler et al., 2012. Agronomy Journal

This UC Davis study was carried out on a crop field on each of 3 dairies in Stanislaus Co. in 2007 and 2008. This is the summary N balance. Nitrogen inputs and outputs were made on the silage corn crops in the two years and on the winter forage crops in between those two corn crops – oats or triticale. On farm 1, there was also a late summer/fall crop of sudangrass produced after the corn and before the triticale. Note that all three farms had very sandy soil. In all 3 fields, mineral fertilizers and dairy lagoon water were applied. The N applied shown here includes both inorganic and organic forms. You can see the extremely high amounts of N applied over about 1.5 years, also very high crop N removals. Also, note the huge gap at Farm 1 and Farm 2 between N applied and N harvested in the crop. On farm 3 where the imbalance was smaller and appears to comply with the waste discharge requirement (Dairy General Order, Central Valley Regional Water Quality Control Board), the estimated leaching loss is still quite substantial. You can also think what these leaching numbers represent in terms of commercial fertilizer value at approximately 50 cents (or more) per lb of N.

The two common types gravity irrigation are furrows or borders (that is not the irrigator wading around out there, but rather our staff research associate taking water samples). With smaller heads of water such as with some wells and very long fields, it may take 4-12 hours to get the water across the field, leading to very non-uniform applications of water and manure nutrients, and likely causing very high nitrate leaching in part of the field. But even where the irrigator has a large heads of water available, and therefore short irrigation sets with good uniformity, the soils on some fields are so permeable that even a single irrigation will leach much of the nitrate present in the soil beyond the reach of roots, as shown by research done by UC Coop Extension about 10 years ago.

Surface irrigation systems

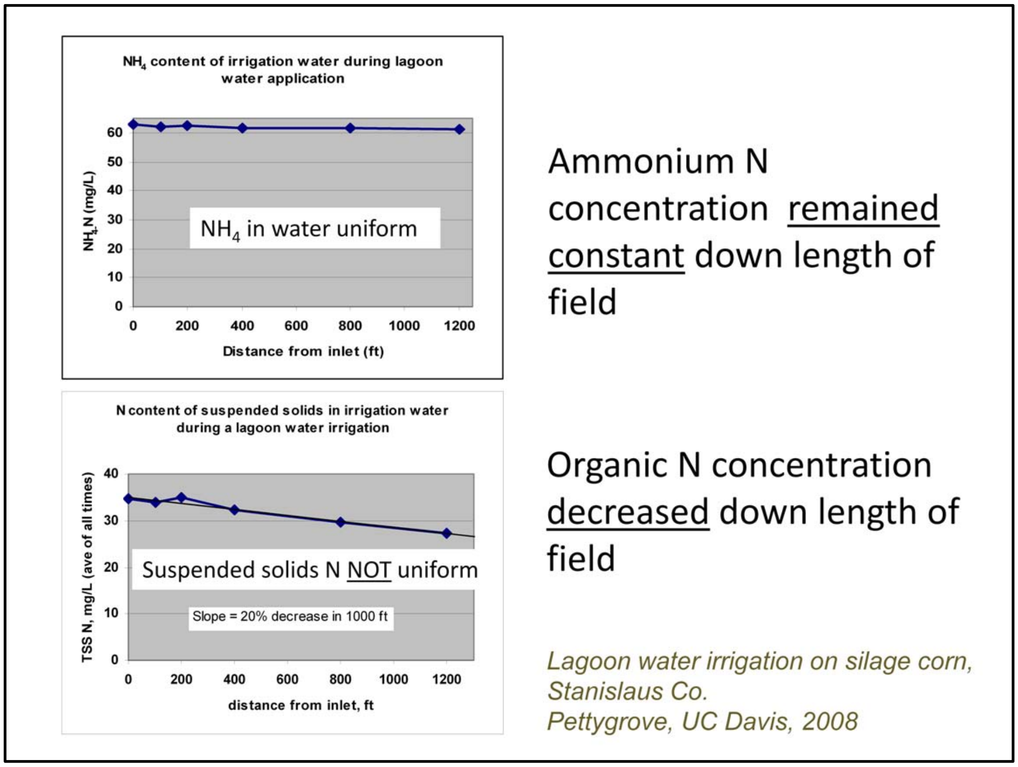
PROBLEM:

- Potentially low efficiency, non-uniform
- Additionally, poor distribution of lagoon water solids

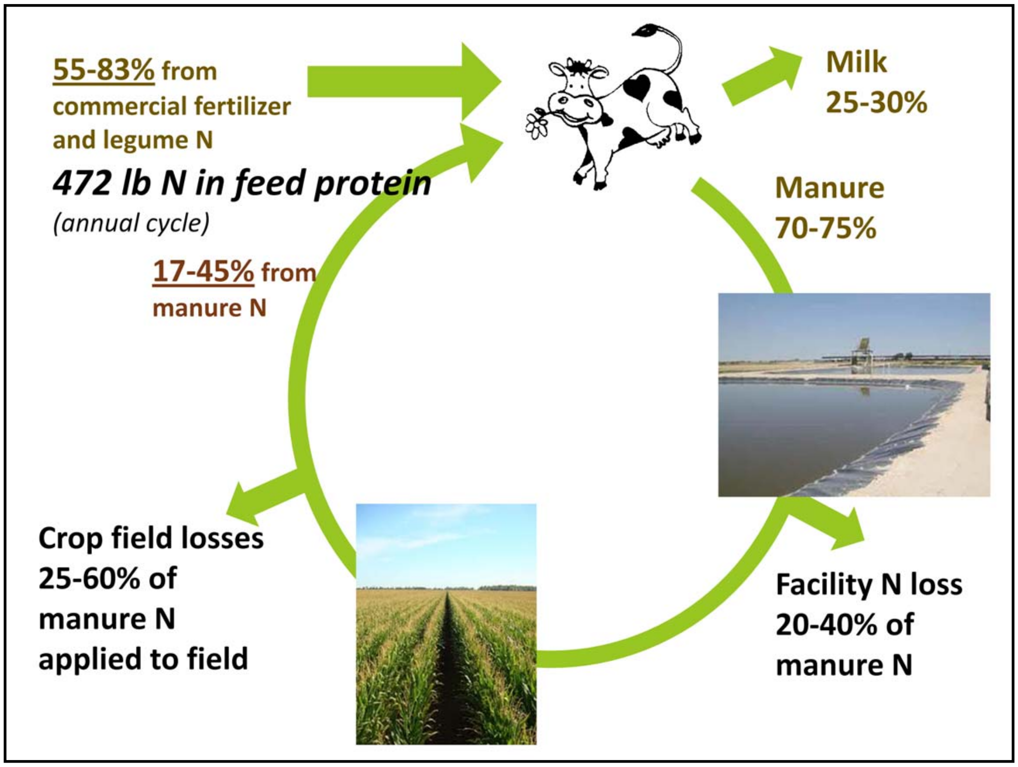
SOLUTIONS?

- Faster advance of water, shorter fields
- Delay lagoon water injection during irrigation
- Convert to pressure irrigation system

The solutions and the feasibility of solutions is very site specific. A rough estimate we have made is that in the southern SJV, 30% of the ground farmed to forage crops with dairy manure is highly permeable. It is difficult to limit leaching of nitrate on these soils with “standard practice”. Center pivot irrigation is a potential solution, but that entails high initial expense for the system, and it won’t work in odd-shaped or small fields or where the farmer cannot afford to give up the corners. Also, it’s not clear that dairy lagoon water could be applied through these systems.



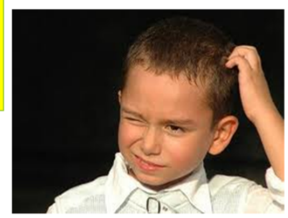
Where dairy lagoon water is applied in the irrigation, there is also the potential for settling of small particles of manure particles during the irrigation. Here are measurements collected by UC researchers in 2008 on a dairy in Stanislaus Co. This was a reasonably uniform, fast irrigation. We measured both ammonium N and organic N in the suspended solids down the length of the field during the irrigation. Ammonium concentration was uniform at 60-63 ppm N, indicating that there was little or no volatile NH3 loss. In contrast, for organic N there was a decrease of about 20% from 35 ppm to 28 ppm, probably due to settling of particles. The resulting non-uniformity would be in addition to whatever resulted from non-uniform irrigation water application, and when repeated at each irrigation, could -- over a period of several years -- lead to non-uniform N availability to the crop.



Design and operation of a dairy manure waste recycling system has to deal with a wide range of uncertainty in the proportion of N excreted as manure N that is lost from the system – mainly as ammonia from the facility and nitrate leaching from fields.

In this scenario, manure N from one milk cow recycled and eventually harvested in forage could be
-- as low as **79 lb N**
-- as high as **198 lb N**

ranging from 24-60% of N excreted as manure



With this much uncertainty in the losses, it is not easy to design a waste recycling system – sizing wastewater pipes, amount of land needed, etc.

R&D needs to improve N use efficiency

- Low-leaching irrigation methods for highly permeable soils
- Adapt soil nitrate and plant tissue testing to forage systems
- Establish field-scale research sites for testing combinations of practices

Here is what is needed to move ahead. First, adoption of improved irrigation design and operation, especially for the most permeable soils – perhaps 20-30%?-- of the soils on dairy crop fields.
Second : Soil nitrate testing – especially use of the Pre-Sidedress Nitrate Test, which has been shown valuable in other parts of the country and on vegetable crops in California and is now being used by row crop farmers in the coastal veg production. There is a quick test version of this. (Also, these test strips can be used to check for presence of nitrate in irrigation water.)
Third, farm-scale research must be done where combinations of practices can be tested and nitrogen can be followed over time. The barrier to this has been the difficulty of doing test plots where dairy lagoon water is applied through the irrigation system and where applications of organic forms of nitrogen are a significant component of the system.

Other R&D needs

- Adaptive management tools
- Determine gaseous N losses from manured fields
- Determine alfalfa N credits
- Better estimates of N release rate of organic N, and validation in field tests
- Convert manure to solids to organic fertilizers usable on a wider range of crops

Adaptive management tools are practices that provide feedback to a producer to evaluate over time (1 or more years) whether N Use efficiency is improving. Such tools would include: N input/output records for each field; the end of season cornstalk nitrate test that is being used by silage corn growers in the northeast US with great success. In some cases shallow monitoring wells may provide feedback, and often tracking amount (depth) of water applied compared to crop ET estimates. Yield trials are an excellent tool, but are inconvenient to conduct where the crop is chopped for silage, requiring weighing of trucks or trailers.

Converting manure to more widely usable forms is needed. Some forms of waste, such as biodigester residues and vacuum-collected manure have not so far been well characterized for agronomic performance.