GROUNDWATER PROTECTION IN CALIFORNIA: NITROGEN PLANNING AND REPORTING

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ABSTRACT

Concern over the environmental consequences of nitrogen released into the environment from agricultural operations goes back at least to the 1970s. Through the federal Clean Water Act (1972) and various state laws dating to that same time period, government has had the power to regulate nitrogen use for decades. However, only in recent years have serious attempts to restrict agricultural N usage become widespread. In California several Regional Water Quality Control Boards have recently introduced various forms of agricultural nitrogen use reporting. This information is to be used to estimate the 'nitrogen balance' for particular crops, and growers. The assumption behind nitrogen balance estimation is that N applied to fields (from any source, including fertilizer, amendments or nitrate in irrigation water) that is not removed in harvested products is at risk of eventual release into the environment. While there are multiple pathways for N release (volatilization and denitrification, for example), the reality is that a significant fraction (often a majority) of N released from agricultural fields will usually be in nitrate form, lost through leaching. The resulting pollution of groundwater is the primary focus of regulatory concern in California. In irrigated production of high-value crops it is exceedingly difficult to manage nitrate leaching losses to meet exacting environmental standards; however, significant improvements in nitrogen use efficiency are possible for many growers. In this workshop we will explore the concept of nitrogen balance in crop production, and suggest ways in which growers can improve the efficiency of their N management practices.

Regulatory interest in non-point source nitrogen pollution from farms dates back decades. Until recent years regulatory scrutiny was divided between threats to surface water (mostly related to eutrophication) and human health concerns over elevated NO_3-N in groundwater; excessive intake of NO_3-N can reduce the capacity of blood to carry oxygen, a condition called methemoglobinemia. However, a study commissioned by the California legislature in 2008 has firmly focused political and regulatory attention on groundwater protection. The study (Harter et al., 2012) found that in regions of intensive agriculture the majority of N loading to groundwater came from agricultural operations. In response, the State Water Resources Control Board, through its Regional Boards around the state, has begun implemented nitrogen management planning requirements and annual nitrogen use reporting. This evolving regulatory program poses significant threat to growers, particularly growers of high value horticultural crops, which historically have received heavy fertilization and ample irrigation.

The concept at the heart of this regulatory scheme is that efficient N use requires reasonable proportionality between the amount of N applied to fields (from all sources, including fertilizer, organic amendments and nitrate in irrigation water) and the amount of N removed in harvested products. Nitrogen applied but not removed in the harvest is considered likely to be lost from the field over time; while there are a number of other N loss mechanisms (volatilization, denitrification, etc.), recent research suggests that nitrate leaching often makes up the bulk of N losses under typical irrigated field conditions. This concept of ‘N balance’ is the foundation of both the N management planning process and N use reporting. N balance can be expressed either as a ratio (applied/removed) or as a difference (applied - removed). In California there is a precedent for using the ratio approach; the dairy industry regulatory program evaluates whole-farm efficiency on the basis of the ratio of N applied to N removed. However, the regulatory scheme for other crop systems appears to be moving toward the difference method as the yardstick of performance.

As currently managed, California’s major crops vary widely regarding their N balance. To illustrate this, Table 1 summarizes typical N fertilization rates, crop N uptake and harvest N removal for some important vegetable crops. N balance is driven by two factors: the rate of fertilization, and the fraction of crop biomass M removed with harvest. It is instructive to contrast the N dynamics of cauliflower and processing tomato production. In both cases current fertilization rates tend to be somewhat lower than the amount of crop N uptake. However, these crops have very different fractions of crop biomass N that is removed with harvest (about 60% for tomato compared to only about 30% for cauliflower). Consequently, the N balance of processing tomatoes could be improved substantially by moderate adjustment to fertilization rates, while for cauliflower it is unreasonable to assume that a low N balance could be achieved solely through a reduction in fertilization. Efficient N management of crops that leave a large quantity of N in crop residue requires consideration of N dynamics across crops grown in rotation.

Table 1. Approximate N balance (fertilizer N applied – N removed in harvest) for major California vegetable crops.

	Pounds of N per acre			
Crop	Seasonal N fertilization	Seasonal crop N uptake	N removed with harvest	N balance (N applied – N removed)
broccoli	180-240	250-350	90-110	90-130
cauliflower	240-280	250-300	70-80	170-200
celery	220-280	200-250	140-160	80-120
head lettuce	140-200	120-160	60-90	80-110
processing tomato	170-250	200-260	110-170	40-80
spinach	120-180	100-130	70-90	50-90

As a measure of potential N loading to groundwater the simplistic analysis presented in Table 1 doesn’t tell the whole story. In many fields there are significant sources of N in addition to fertilizer. Organic amendments (manures, composts, etc.) may release substantial amounts of N over a cropping season. Where irrigation water contains more than a few parts per million (ppm) NO_3-N the seasonal N application with irrigation can be agronomically significant.

Another factor that is not captured in Table 1 is the impact of cropping intensity. Leafy greens are often double or even triple-cropped, meaning that the potential annual loading to groundwater can be high, even where each individual crop is responsibly managed.

The potential risk that regulation based on groundwater quality protection poses to California growers can be illustrated by comparing the water quality target for NO_3-N concentration with typical NO_3-N concentration in leachate from fields. The federal drinking water standard is 10 ppm NO_3-N. By contrast, the soil solution NO_3-N concentration in fertilized root zones is seldom below 20 ppm, and is often > 100 ppm, particularly after fertilizer application. As soil solution is leached, whether by irrigation or precipitation, there is some degree of dilution, but not nearly enough to approach a flow-weighted mean of 10 ppm NO_3-N. In fact, the limited rainfall received in California is a major reason why the nitrate pollution problem is so severe; there is less dilution of leachate than occurs in regions of higher precipitation. Direct measurements of nitrate leaching are difficult to obtain, but where they have been made NO_3-N concentration several times the 10 ppm regulatory standard have been common (Arpaia and Lund, 2003; Bottoms et al, 2014). The NO_3-N concentration of tile drainage provides a valid surrogate measure of typical leachate NO_3-N; water reaching tile drains has already moved too deep to be recovered by crops, and relatively little denitrification is likely to occur between tile drain depth and first-contact groundwater. Hartz et al (2016) found that tile drainage from coastal vegetable farms were consistently above 60 ppm NO_3-N, while Los Huertos et al. (2001) reported that drainage ditches receiving discharge from tile drainage systems commonly had NO_3-N concentrations exceeding 70 ppm.

The challenge presented by nitrogen regulatory programs can be illustrated by considering how restrictive the 10 ppm NO_3-N target is. A crop production system in which a total of 12 inches of water was leached (from precipitation and irrigation combined) could only contain 28 pounds of NO_3-N per acre. Comparing that amount to the N balance values in Table 1 shows the magnitude of the problem. Clearly, for California growers, and the consultants who advise them, the developing program of nitrogen regulation provides a strong incentive to improve current N management practices. Whereas in the past the focus of N management was almost entirely on ensuring the optimal crop, we will increasingly need to consider the environmental footprint our management practices make. This workshop will focus on methods to improve N management efficiency, by realistically estimating crop N requirements, making better use of non-fertilizer N, and improving irrigation management.

The future path of N regulation is not clear. The current paradigm appears to be to identify crops, and individual growers, with particularly high N balances, and work to improve them over time. However, environmental and social justice groups, believing this incremental approach to be insufficiently protective of groundwater, are challenging it with political lobbying and lawsuits. At a minimum, regulation will impose additional costs, and possibly some limitation on use of N fertilizers.

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