INNOVATIVE RESEARCH ON NUTRIENT MANAGEMENT

IN CALIFORNIA'S CENTRAL COAST

RESOURCE CONSERVATION DISTRICT OF MONTEREY COUNTY

Compiled by the Resource Conservation District of Monterey County

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OVERVIEW

This document summarizes innovative research and informal trials and experimentation pertinent to understanding water quality impacts of agricultural conservation actions to reduce transport of nutrients to surface water and groundwater in California's Central Coast region. Where possible, peer-reviewed, replicated research trials with appropriate controls are cited. However, final reports from informal experimentation are also included so that the insight and understanding garnered from that work is captured as well. We recognize that non-peer reviewed sources may not offer the same confidence in efficacy, but they do capture what growers in the Central Coast are willing to do.

The best management practices related to agricultural nutrient management and drainage water quality included in this document are listed in Table 1. Implementation of practices in the formal and informal research trials referenced in this text may not specifically follow NRCS Conservation Practice Standards, as they constitute innovative approaches. As indicated in Table 1, some of these practices are implemented in the production area, while others may be installed at edge of field or otherwise beyond the crop field borders.

Practice	**In-field**	**Field-Edge**
Cover Crop	X	
High Carbon Amendments	X	
Irrigation System, Micro-Irrigation	X	
Irrigation Water Management	X	
Nutrient Management	X	
Constructed Wetland		X
Denitrifying Bioreactor		X

TABLE 1. LIST OF CONSERVATION PRACTICES THAT MAY REDUCE TRANSPORT OF NUTRIENTS TO SURFACE WATER AND GROUND WATER.

INTENDED USE OF THIS DOCUMENT

The intent of this document is to summarize regionally-specific information on innovative practices to help inform water quality conservation efforts of growers, consultants and conservation partners working in the region. Ultimately, the management practice(s) selected by growers in the Central Coast region will depend on economic factors, crop and site location (slope, microclimate, soils, etc.), and management concerns (e.g., food safety in fresh produce), among other site- and producer-specific factors. The information herein offers evidence to help guide those tasked with managing working lands for best possible conservation outcomes.

Financial and technical resources are available for growers and landowners to implement conservation practices on their farm or ranch via the USDA Natural Resources Conservation Service (NRCS), local Resource Conservation Districts, the California Department of Food and Agriculture (CDFA)'s Office of Environmental Farming & Innovation, local non-profits, and private contractors. Interested parties should contact their local NRCS or RCD office for more information.

IN-FIELD PRACTICES

In this section, we summarize some of the innovative research on regional nutrient management recently conducted via in-field practices. We focus on innovative approaches to implementation of cover crops, high carbon amendments, micro-irrigation systems, irrigation water management, and nutrient management.

Cover crop

FIGURE 1. MOWING OF MUSTARD FURROW COVER CROP IN STRAWBERRY FIELD. CREDIT: RICHARD SMITH, UCCE.

Winter-killed cover crops: Planting a winter-killed cover crop is a strategy to use cover crops to scavenge soil nitrogen in the winter without interfering with the early spring planting schedules. From 2010 to 2012, Heinrich et al. (2014) evaluated the potential use of winter-killed cover crops in the Central Coast's cool-season vegetable systems to understand the benefits for reducing nitrate-nitrogen (NO_3-N) leaching. A cereal rye was evaluated as a full-season cover crop (allowed to grow full term) and as a partial-season cover crop (cover crop killed with herbicide approximately 62 days after emergence) and was compared to a fallow control treatment. The trial was ended on March 11 in the first year of the trial and Feb 16 in the second year. Heinrich et al. (2014) found that the full season cereal rye cover crop reduced NO_3-N leaching by 64% and 75% in years one and two relative to the fallow treatment. The full season cover crop was able to uptake 142 lb/acre of NO_3-N relative to fallow in both years regardless of the yearly variations in the timing and amount of precipitation. The lysimeter extract NO_3-N levels were reduced but were never below the EPA drinking water standard of 10 mg/L^{-1} of NO_3-N. The partial-season cover crop had no effect in reducing NO_3-N leaching compared to the fallow treatment in year one which received 35% more rainfall than the historical average. The partial-season cover crop was able to significantly reduce soil NO_3-N levels compared to the fallow treatment in year two, but the crop's ability to reduce NO_3-N leaching was limited by the killing of the cereal rye while the crop was young. Once the cover crop was killed with herbicide, transpiration stopped, and residues released NO_3-N nitrogen back into the soil. Due to the rain in the late winter, the nitrogen was moved further into the soil profile in the partial-season cover crop treatment. As a result, the authors suggest that the partial-season strategy will likely have minimal benefit in reducing NO_3-N leaching in a normal to wet rainfall year (Heinrich et. Al. 2014).

Cover crops in strawberry furrows: Cover-cropped furrows in an organic strawberry system using mustard has shown to provide benefits in reducing NO_3-N leaching (Brennan and Smith 2018). The use of plastic mulch is a common practice for strawberry production; as a result, runoff becomes concentrated in furrows during the winter rains and produces high runoff and erosion risk. In an effort to incorporate cover crops into the strawberry production system for leaching and runoff reduction, the authors evaluated two rates of mustard as a cover crop for strawberry furrows. Three mustard seeding rates were evaluated: no cover crop, 1x, and 3x. The 1x seeding rate was approximately 42-37 g of seed per 100 feet of furrow and the 3x seeding rate was approximately 3-4 times greater than the 1x rate. The treatments were planted in December and November for years one and two of the trial respectively, and the mustard plants were cut off near the soil surface using a string trimmer in early February of each year. Mustard shoot nutrient concentrations were only measured in year one of the trial and ranged from 4% to 5.9% Nitrogen (N), 0.48% to 0.58% Phosphorus (P) and 1.9% to 2.5% Potassium (K). Brennan and Smith (2018) found a trend of 10% lower N concentrations in furrow cover crops in the 3x seeding rate treatment. The authors suggest the higher seeding rate furrow cover crop has the potential to reduce NO_3-N leaching due to mustard's ability to accumulate nitrogen in their shoot residue (Brennan and Smith 2018). There are potential benefits in reducing nitrogen in runoff water with the furrow cover crops, but the authors warn that the N scavenged by the cover crop could be subject to subsequent leaching in spring rains if the high nitrogen content residue decomposes quickly after the cover crop is mowed. The authors are conducting ongoing research on this practice to better understand nitrogen dynamics.

References:

Brennan, E. B. and Smith, R. F. 2018. Mustard Cover Crop Growth and Weed Suppression in Organic, Strawberry Furrows in California. HortScience 53(4): 432-440.

Heinrich, A., Smith, R., and Cahn, M. 2014. Winter-killed Cereal Rye Cover Crop Influence on Nitrate Leaching in Intensive Vegetable Production Systems. HortTechnology 24(5): 502-511.

High Carbon Amendments

FIGURE 2. COMMERCIAL APPLICATION OF ALMOND SHELLS AT 5 AND 10 TONS/ACRE. CREDIT: RICHARD SMITH.

Post-harvest soil NO_3-N in the fall is prone to leaching due to winter rains. One approach for managing the fall-season post-harvest soil NO_3-N pool is the use of high carbon organic amendments during the winter fallow period to immobilize soil NO_3-N, thereby reducing leaching. Smith et al. (2019) evaluated this approach using 4 different carbon source applications during the winter fallow period: (1) 5 tons/acre of almond shells; (2) 10 tons/acre of almond shells; (3) 2.5 tons/acre of glycerol; (4) a combination of 1.25 tons/acre of glycerol and 5 tons/acre of almond shells. The almond shells were ground to 0.5 mm in size. All treatments reduced the load of NO_3-N in the top three feet of soil by nearly half compared to the untreated control at the end of the winter fallow period. The almond shells treatment at 10 tons/acre reduced the subsequent lettuce crop yield; this was not observed from the other treatments. These treatments show an alternative approach to reducing NO_3-N leaching in the winter fallow period, but the high cost of using these amendments continues to be a challenge.

References:

Smith, R., Muramoto, J., Tourte, L., Haffa, A., Melton, F., and Love, P. 2019. Immobilization of nitrate in fallow winter vegetable production beds. UC Cooperative Extension Salinas Valley Agriculture Blog.

Irrigation system, micro-irrigation

Micro-sprinklers can be used to help leach out salts from the root zone and are commonly used in strawberries given their sensitivity to salinity (Dara 2012), however excessive leaching can increase risk of NO_3-N movement beyond the root zone. To understand implications for water conservation and pathogen pressure, Dara (2016) evaluated micro-sprinkler use in strawberry production in Santa Maria, CA. A block containing 60 beds (306-365 ft long) contained aluminum sprinklers in furrows every 40 ft; a second 60-bed block had micro-sprinklers installed on every third bed and placed 16 ft apart with a 15 ft spacing within a bed. Six 20 ft long plots were marked to measure plant growth, pest and predatory mite populations, and powdery mildew and botrytis fruit rot parameters within the two treatment blocks. During the three-week establishment period in November 2015, the aluminum sprinklers delivered 120,000 gallons of water over 16 hours of total irrigation while micro-sprinklers delivered 81,600 gallons over 34 hours of total irrigation. In other words, the micro-sprinklers saved 32% of water during the establishment phase. The use of the micro-sprinklers continued for 15 minutes twice a week for the rest of the production period. There was no significant difference in total marketable berries when the seasonal averages for grower standard (aluminum sprinklers) and micro-sprinkler plots were compared. Plant canopy was smaller in January and February in the micro-sprinkler treatment, then had no differences when canopy was measured from January to March. Useful insect pest data was not obtained due to sparse numbers and uneven distribution of spiders and predatory mites. Powdery mildew severity was significantly less in micro-sprinkler treatment than the grower standard on two of three sampling dates. Botrytis fruit rot was generally less severe in the micro-sprinkler treatment, with significant differences found for two of four sampling dates which each occurred three days after harvest. This evaluation of micro-sprinklers in strawberries showed a significant reduction in overhead irrigation water use (and likely reduced excessive leaching or runoff) without affecting the marketable yield, and with generally less severe disease. Additionally, given that less pressure is required to deliver water through micro-sprinklers, their utilization could lead to energy savings.

FIGURE 3. MICRO-SPRINKLER USE IN STRAWBERRIES. CREDIT: SURENDRA DARA (DARA 2016).

References:

Dara, S. K. 2012. Salt injury in strawberries. UCCE eNewsletter, Strawberries and Vegetables. Accessed September 6, 2021 at: http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=6820.

Dara, S. K. 2016. Micro-sprinklers in strawberry production. CAPCA Adviser Magazine. Accessed September 6, 2021 at: https://capca.com/wp-content/uploads/2017/12/Micro_Sprinklers_Strawberry_Production_SDara_Feb2016.pdf.

Irrigation water management

Tools for irrigation water management have advanced over the past 40 years from soil moisture technology to programs for evapotranspiration (ET)-based irrigation scheduling. The adoption of these water management tools have yet to be widely adopted in vegetable production due to a typical operation's number of fields concurrently managed and coordinated, the diversity of vegetable crop rotations per season, and challenges with scheduling irrigations to optimize water use (Cahn & Johnson 2017). Still, ongoing research indicates the utility of these approaches for improving water use efficiency and for reducing losses of NO_3-N via runoff or leaching. Given that the quality of surface water and groundwater in the Salinas Valley is highly impacted by NO_3-N, improved tools for irrigation water management can help reduce runoff and leaching and enhance regional water quality.

Drip germination: It is well known that drip irrigation systems are more efficient than sprinkler systems with regard to water use; however, sprinkler irrigation is commonly used for crop germination. Cahn and Smith (2020) investigated the use of buried drip irrigation for germination to determine feasibility and potential water savings when compared to sprinkler systems. They compared use of the two irrigation systems for germination of head and romaine lettuce in the Central Coast region. Their results showed that, on average, more water was conserved and less NO_3-N was lost with drip irrigation, particularly on medium-textured soils and/or places where wind and soil-crusting negatively affect germination with sprinkler irrigation.

ET-based irrigation scheduling: A major advancement in irrigation water management is ET-based irrigation scheduling. ET-based irrigation scheduling is a practice that optimizes water application relative to plant growth and conserves water. Johnson et al. (2016) evaluated irrigation trials for broccoli and iceberg lettuce using ET-based irrigation scheduling in Salinas, CA in 2012 and 2013. The study evaluated two irrigation decision models, NASA's prototype Satellite Information Management System (SIMS) and UCANR's CropManage, and compared these to the grower standard practice. All treatments received equal amounts of water during the germination phase via sprinklers. Following germination, crops were drip irrigated; during this phase, both models used daily reference ET_o data to determine crop ET, with a target of 100% replacement of crop water use. Meanwhile, the grower standard practice followed a 150% to 175% ET replacement schedule. Cumulative water applications to lettuce and broccoli crops during the drip irrigation phase of the study were as follows:

	Grower standard practice	*SIMS*	*CropManage*
2012 Lettuce	280 mm	168 mm	183 mm
2013 Lettuce	254 mm	180 mm	170 mm
2012 Broccoli	394 mm	249 mm	236 mm
2013 Broccoli	470 mm	290 mm	272 mm

TABLE 2. COMPARISON OF TOTAL POST-GERMINATION WATER APPLICATIONS BETWEEN GROWER STANDARD PRACTICE AND TWO ET-BASED IRRIGATION SCHEDULING TOOLS (JOHNSON ET AL. 2016).

Drip irrigation totals were highest in the grower standard practice treatment, followed by the SIMS model treatment, and the least for the CropManage treatment. In both years of the trials, marketable yields were equivalent with industry averages in all treatments. This study by Johnson et al. shows that marketable yields of lettuce and broccoli can be achieved with full replacement irrigation regimes, effectively avoiding overapplication of water and associated economic and ecological costs (NO_3-N and water loss).

References:

Cahn, M. D. and Johnson, L. F. 2017. New Approaches to Irrigation Scheduling of Vegetables. Horticulturae 3(2): 28.

Cahn, M., and Smith, R. 2020. Season-long Use of Buried Drip Irrigation Implications for Surface Applied Fertilizer. 2020 UCCE Irrigation & Nutrient Management Meeting.

Daugovish, O., Faber, B., Cahn, M., Dara, S. 2016. Increasing Number of Drip Irrigation lines for water conservation during Strawberry establishment. International Journal of Fruit Science. 16(S1):108-117.

Johnson, L. F., Cahn, M., Martin., F., Melton, F., Benzen, S., Farrara, B., Post., K. 2016. Evapotranspiration-based Irrigation scheduling of Head Lettuce and Broccoli. HortScience 51(7):935-940.

Nutrient Management

As a conservation practice, nutrient management encompasses the principles of the 4 R's including Right Source, Right Rate, Right Time, and Right Place (Johnson 2011):

1. Right Source: matching the right fertilizer product with soil properties and crop need;
2. Right Rate: matching application rates with crop need;
3. Right Time: synchronizing nutrient availability with crop demand;
4. Right Place: placing and keeping nutrients where the crop can get to them and where nutrient use efficiency will be maximized.

The 4 R's constitute the organizing principles behind nutrient management recommendations and approaches discussed below. Fine tuning nutrient management can begin with baseline soil and water sampling and using the information to adjust nitrogen fertilizer rates. Land managers can refer to the UC Vegetable Research and Information Center Production Series for fertilization guidance.

Full-season approach: The UC Cooperative Extension of Monterey County has suggested a full-season approach to manage the pool of residual soil NO_3-N in multi-crop (per year) vegetable production systems to prevent leaching beyond the root zone (Smith 2019). This approach seeks to account for different challenges to nutrient management that occur throughout the year. For example, the first vegetable crop cycle on the Central Coast is typically in late winter and early spring. During this time, the residual soil NO_3-N pools can vary depending on the amount of winter rain that was received. In dry years there may be sufficient residual NO_3-N to adjust fertilizer programs; in wet years that may not be possible. As a result, land managers can combine regular soil and water sampling with referencing UC Cooperative Extension crop nutrition guidelines in order to match application rates with crop need and achieve the Right Rate of fertilizer application.

The second vegetable crop cycle in the Central Coast is typically spring through fall. After the first crop, the residual soil NO_3-N builds up from mineralization of soil organic matter, unused fertilizer nitrogen, and mineralization of crop residues. Smith (2019) suggests using scavenging crops, such as broccoli, cauliflower, and cabbage, during the second crop cycle in order to capture the pools of NO_3-N that move deeper into the soil profile after the first crop cycle. This method suggests measuring the soil NO_3-N availability contributed by the first crop residues with a soil NO_3-N test taken before the first fertilization event for the second crop. Smith (2019) utilized this approach in 18 lettuce production fields to evaluate the possibility of utilizing residual soil NO_3-N to meet crop needs. At harvest, 12 of those 18 fields had soil NO_3-N levels below 20 ppm, indicating that this approach has potential for high crop nutrient use efficiency.

Accounting for nutrients in crop residues: Another approach to nutrient management in the Central Coast region involves the incorporation of nitrogen mineralization from cole crop residues into fertilization nitrogen rates. Smith et al. (2016) evaluated 14 broccoli, 8 cabbage, and 8 cauliflower fields and found the above-ground residue nitrogen content at harvest averaged 367, 367, and 319 kg per hectare respectively and suggested the likelihood of rapid nitrogen mineralization upon soil incorporation. This study found cole crops to have a high capacity to scavenge soil mineral nitrogen (SMN) due to their deep roots. To ensure the Right Rate of fertilizer application, the level of residual SMN should be taken into account when determining nitrogen fertilization requirements. Smith et al. (2016) suggest soil NO_3-N sampling before each scheduled fertilizer application by sampling the top 30 cm during the first half of the season and then sampling deeper later in the season. Additionally, they suggest only applying enough nitrogen to bring soil nitrogen up to the crop's response threshold (after which the crop shows no response to fertilizer additions) to draw down SMN by harvest.

Accounting for nutrients in irrigation water: Field trials have been conducted to evaluate the use of high NO_3-N irrigation water as a fertilizer source in lettuce and broccoli in the Salinas Valley (Cahn et al. 2017). Both trials showed crop biomass and N uptake increasing linearly with increasing irrigation water NO_3-N concentration. The 2015 trials demonstrated that irrigation water NO_3-N was at least as effectively used by the crop as fertilizer N. These trials illustrate the utility of using the excess NO_3-N in irrigation water as fertilizer N which, to achieve the Right Rate of application, would involve adjusting the fertilizer program to account for the levels of NO_3-N in the irrigation water.

References:

Cahn, M., Smith, R., Murphy, L., and Hartz, T. 2017. Field trials show the fertilizer value of nitrogen in irrigation water. California Agriculture 71(2): 62-67.

Johnson, J. 2011. 4Rs Right for Nutrient Management. USDA Natural Resources Conservation Service Iowa. Accessed November 22, 2021 at: https://www.nrcs.usda.gov/wps/portal/nrcs/ia/technical/ecoscience/nutrient/nrcs142p2_008196/.

Smith, R. 2019. Full-Season Nitrogen Management of Vegetables. 2019 Irrigation & Nutrient Management Meeting Presentation. UC Cooperative Extension Monterey County.

Smith, R., Cahn, M., Hartz, T., Love, P., and Farrara, B. 2016. Nitrogen Dynamics of Cole Crop Production: Implications for Fertility Management and Environmental Protection. HortScience 51(12):1586-1591.

FIELD-EDGE PRACTICES

In this section, we summarize some of the innovative research on regional nutrient management recently conducted via field-edge practices. We focus on innovative approaches to implementation of constructed wetlands and denitrifying bioreactors.

Constructed Wetland:

A constructed wetland is an artificial wetland that uses biological processes to improve water quality. This approach has been utilized throughout the Central Coast region. In 2006, the Molera (constructed) wetland was established on a Monterey County parcel located at the confluence of Tembladero Slough and the Old Salinas River Channel near Castroville (Clarke and Watson 2013). Since then, the wetland has been operated as an off-line, downstream experimental watershed pollution treatment system that treats surface water that includes substantial agricultural runoff. The 1.5-hectare (3.5 acres) wetland consists of 285 meters of sinuous channel that drains via sheet flow across 1.5 acres of shallow wetland back into the slough. The project summary posted by the Central Coast Wetlands Group reported the wetland reduced the concentration of NO_3-N by 5 to 20 mg/L depending on the residence time. The authors suggest construction of a much larger wetland would be needed to make a substantial impact on the watershed nutrient load. Miller et al. (2014) analyzed the limitation of temperature, carbon, and NO_3-N supply on NO_3-N removal by treatment wetlands at the Molera Wetland using a predictive model-based approach. The monitoring data showed the wetland inlet NO_3-N concentrations to have ranged between 0.39 mg/L and 84.9mg/L and the range of outlet NO_3-N concentrations was 0.2 mg/L to 65.1 mg/L. Miller et al. (2014) found with median carbon concentrations during the coolest month (January) the modeled average NO_3-N removal was 1.29 mg/L and during the warmest month (August) the modeled average NO_3-N removal was 7.91 mg/L. This thesis study showed that NO_3-N removal was greatest at higher temperatures and higher inlet NO_3-N concentrations based on the *a priori* Akaike's Information Criterion (AIC) analysis. The standardized model coefficient for the best

FIGURE 4. . TIMELINE OF THE CONSTRUCTION AND ESTABLISHMENT PHASES OF THE MOLERA ROAD TREATMENT WETLAND. THE TOP IMAGE IS FROM 11/21/05, THE SECOND FROM 3/9/06, THE THIRD FROM 6/6/06, THE FOURTH FROM 7/11/06, AND FIFTH IMAGE FROM 11/30/06. CREDIT: CCWG.

model in the study by Miller et al. (2014) demonstrated the initial NO_3-N concentrations had the largest influence on NO_3-N removal, followed by temperature, and then carbon.

In 2007, the Central Coast Wetlands Group constructed the 'Sea Mist Wetland' in the Moro Cojo Slough area near Castroville, California. The 21-acre treatment wetland is comprised of three ponds with connecting channels and receives water from approximately 150 acres of irrigated agriculture. The delisting consideration letter written by the Central Coast Wetlands Group to the Regional Water Quality Control Board in 2020 reported the wetland had an estimate of 98,000,000 L of total flow during their sampling period and calculated 4,000 kg of NO_3-N was removed during the first year of sampling. The average NO_3-N concentration at the inflow of the Sea Mist Wetland was measured as 46.5 mg/L and the average NO_3-N at the outlet of the wetland was measured as 5 mg/L (CCWG 2020).

The Central Coast Wetlands group also constructed the 12-acre 'Castroville Slough Treatment Wetland' in the Moro Cojo Slough watershed near Castroville, California in 2016 The treatment wetland is 1.25km in length, preceded by a twelve-chamber experimental bioreactor that treats the water prior to draining into the wetland itself. The bioreactor and treatment wetland receives water that drains approximately 1000 acres of farmland; this water can flow into the experimental bioreactor or through bypass lines directly to the treatment wetland. Nutrient concentrations were collected at various points and during all sampling events (2017-2020). While inlet concentrations ranged from approximately 5-30 mg/L NO_3-N, NO_3-N concentrations at the outflow of the treatment wetland were below 1 mg/L at all sampling events (CCWG 2020).

References:

Clarke, R., and Watson, F. 2013. The Molera Road Experimental Treatment Wetland Project Summary. Central Coast Wetlands Group. Accessed November 22, 2021 at: https://mlml.sjsu.edu/ccwg/wp-content/uploads/sites/23/2020/01/MoleraTreatment.pdf.

Central Coast Wetlands Group. 2020. Moro Cojo delisting consideration letter for the Regional Water Quality Control Board and US EPA. May 2020.

Miller, G., Watson, F., Los Huertos, M., and Clark, R. 2014. Limitations on nitrogen removal by treatment wetlands under maritime climatic conditions. Masters Thesis from California State University Monterey Bay.

Denitrifying Bioreactor

Denitrifying bioreactors are excavated trenches located at the field edge and filled with solid carbon media, such as woodchips (Figure 5), to reduce the concentration of NO_3-N via enhanced denitrification. In order to better understand these denitrification dynamics, one recent study evaluated two woodchip bioreactors to remediate high-NO_3-N tile drainage on two vegetable farms in the Central Coast region (Hartz et al. 2017). The water-holding capacity was

FIGURE 5. COMPLETED DENITRIFICATION WOODCHIP BIOREACTOR. CREDIT: TIM HARTZ (HARTZ ET AL. 2017).

approximately six gallons per cubic foot of volume, or about 5,500 and 2,600 gallons total in each bioreactor at sites 1 and 2, respectively. The bioreactors were filled with untreated scrap construction wood, approximately 70% of the water passing through was free-draining, and the bioreactors were not covered by tarps or soil. The drainage water from the two farm sites' tile drain systems was pumped from collection sumps into the bioreactors at a constant flow rate to achieve approximately 2 days of hydraulic retention time (HRT) based on total water volume. Initially the bioreactors were operated without carbon enrichment for 2 years, nor were they inoculated with denitrifying bacteria. Hartz et al. (2017) reported high dissolved oxygen content (DOC) initially in the effluent water that declined after several weeks. The tile drain effluent had NO_3-N ranges from 100-180 mg/L at site 1 and 60-120 mg/L at site 2. Denitrification rates in the summer dropped the concentration of NO_3-N by an average 8 to 10 mg/L per day of HRT. In the winter, the denitrification process slowed due to lower water temperature, reducing NO_3-N concentration reduction to an average of 5 mg/L per day of HRT. Hartz et al. (2017) noted that due to the high NO_3-N concentration of the tile drainage, the water leaving the bioreactors after 2 days of HRT was often above 100 mg/L and therefore did not reach an environmentally acceptable level. The authors suggest the bioreactor treatment would have to be extended for many days or the rate of denitrification increased with an enriched carbon source to achieve an environmentally acceptable NO_3-N level if treating high NO_3-N tile drainage from coastal vegetables. They concluded that such a bioreactor enriched with a carbon source could achieve complete denitrification within 1.7 days of HRT and suggest that a bioreactor 100 feet by 30 feet by 6 feet should be adequate for a 200-acre farm producing 65,000 gallons of drainage water daily.

The RCD of Santa Cruz County constructed the Bryant Habert (denitrifying woodchip) Bioreactor in the Watsonville Slough sub-watershed that treats tile drain water from 60 acres of nearby farmland that rotates between strawberry, row crops, and fallow periods. Before entering the bioreactor, the tile drain water passes through a sediment basin. The bioreactor was constructed as 150-foot length, 55-foot width, and 5-foot depth, and holds 440 cubic yards of woodchips. After treatment, water leaves the bioreactor and passes through a broad, shallow, vegetated swale leading into the Watsonville Slough. The bioreactor was monitored once per week during one 4-week period after the project was implemented in February 2017. NO_3-N levels entering the bioreactor were 14 mg/L. The hydraulic retention time within the bioreactor was approximately 7 hours. Nitrate levels were reduced by 70-95% resulting in outlet water NO_3-N concentrations to 0.85 to 5.2 mg/L of NO_3-N. The NO_3-N levels were further reduced to 0.61 – 2 mg/L after passing through the vegetated swale. The Bryant Habert Bioreactor has an estimated daily NO_3-N load reduction of 3.65 kg NO_3-N/day (RCDSCC 2017).

References:

Hartz, T., Smith, R., Cahn, M., Bottoms, T., Castro Bustamante, S., Tourte, L., Johnson, K., and Coletti, L. 2017. Wood chip denitrification bioreactors can reduce nitrate in tile drainage. California Agriculture Vol 71(1) 41-47.

Final Report: Pajaro Valley Irrigation and Nutrient Management Program: Bryant Habert Bioreactor Project. 2017. Resource Conservation District of Santa Cruz County (RCDSCC).

CONCLUSION

The practices discussed in this document highlight some of the innovative research relevant to agricultural nutrient management in California's Central Coast region. While the information provided here is by no means comprehensive, it offers partial evidence to help guide those tasked with managing working lands for best possible conservation outcomes related to nutrient management for water quality. Ongoing research on the nutrient management practices discussed in this document should be coupled with attention to operational constraints such as food safety guidelines and the regional economic context in order to ensure viability and potential for widespread implementation of innovative practices. In particular, short-term leases and high land prices in the Central Coast region can make conservation practices involving non-crop vegetation financially burdensome for farmers. We encourage land managers to contact the researchers referenced in this document as well as their local NRCS and RCD offices to learn more about specific practices and their potential applicability to specific farm or ranch sites.