SOIL, WATER, AND CROP PRODUCTION CONSIDERATIONS IN MUNICIPAL WASTEWATER APPLICATIONS TO FORAGE CROPS

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ABSTRACT

Exponential growth of urban areas in California within the last 50 years has resulted in a greater demand for water resources and the production of more human and industrial waste. The application of reclaimed municipal wastewater to forage crops is an efficient way to reuse waste and conserve valuable surface and groundwater resources. However, municipal wastewater can contain high levels of nitrogen and other constituents that can be detrimental to surface and groundwater supplies if it is not carefully applied. Wastewater application to cropland requires fundamental knowledge of soil salinity and fertility, plant water and nutrient use, and wastewater characteristics to successfully monitor and properly irrigate forage crops. Farm managers and wastewater suppliers that are involved with this application process should have a general understanding of soil, plant, and water interactions and the motivation to achieve and maintain adequate agricultural productivity for the operation to be agriculturally and environmentally sound.

Key words: Alfalfa, municipal wastewater, effluent, forage crops, nitrogen, nitrates, salinity, irrigation, groundwater contamination.

INTRODUCTION

The application of reclaimed municipal wastewater to agricultural lands dates back to the nineteenth century in the US and Europe, following the development of modern sewage systems. In many areas of the world, reclaimed wastewater is the principle source of water for irrigating cropland. Most of the wastewater reuse sites in the US today are in arid and semi-arid areas of the Western states (Tchobanoglous et al., 2003). Over the last 50 years many urban areas of California have experienced exponential population growth creating an increased demand for freshwater and increased production of wastewater. As competition for state water increases we are seeing "recycled water" make the transition from "waste" to a valuable resource.

The application of reclaimed municipal wastewater to irrigated crops can be an efficient way to reuse waste and conserve valuable imported and ground water resources. The California State Department of Health Services approves of the application of secondary treated reclaimed municipal wastewater to fodder, fiber, and seed crops because humans

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do not directly consume them (DHS Title 22). As a result forage crops have become a dominant crop in municipal wastewater land application systems throughout the state.

While reclaimed municipal wastewater reuse seems like a sensible approach to alleviating the water problem in California, it can contain high levels of various forms of nitrogen that readily convert to nitrate and can potentially contaminate groundwater if it is over applied to cropland. Nitrates in drinking water sources have been known to cause methemoglobinemia, or “blue baby syndrome”, in human infants less than six months of age. Because of this disorder the current federal standard for nitrate-nitrogen levels in drinking water is 10 ppm (parts per million). Typical nitrogen concentrations in reclaimed municipal wastewater are in the range of 5 ppm to 40 ppm, depending on the source (Page et al., 1983; Pettygrove and Asano, 1984).

There have been several cases in California of improper reclaimed wastewater applications to cropland that have resulted in nitrate contamination of groundwater. Therefore it is important that reclaimed municipal wastewater be applied to cropland with careful thought given to the application site characteristics, wastewater characteristics, crop water use (ET) and nutrient use rates, and other crop production considerations to maximize yield. Applying reclaimed municipal wastewater to cropland requires more attention to these factors than the typical forage grower is accustomed to. This paper will focus on the application of secondary treated municipal wastewater to irrigated forage crops (the term secondary treated municipal wastewater may also be used interchangeably with municipal effluent).

SITE CHARACTERISTICS

The potential of any particular site for agricultural wastewater reuse will be determined by its soil texture, structure, salinity, depth to the groundwater table, and climate. The long-term sustainability of the agricultural operation is dependent upon proper site selection. The main objective of any wastewater reuse operation should be to maximize yields through the most efficient utilization of wastewater resources. The main intent of any wastewater project should never focus on “disposal” but on 100% beneficial reuse. Thus the crop production and environmental characteristics of a site are very important to maximize production, utilize the “recycled resources”, and protect the environment.

Soil texture, the ratio of sand, silt and clay**,** will determine the drainage/leaching characteristics, nutrient retention, and water holding capacity of any given site. Typically clay soil types are finer in texture (heavier) with less drainage/lower percolation, greater nutrient retention, and greater water holding capacity compared to sandy soils. Sandy soils are typically coarser in texture (lighter) with greater drainage/higher percolation, less nutrient retention, and less water holding capacity. Sandy loam soils are more common to arid and dry areas. Loam soils are often best suited for irrigated crop production because they contain intermediate percentages of sand, silt, and clay with adequate rooting depth and water holding / nutrient retention capacities. The best source of soil structure and textural information are Soil Conservation Service soil surveys that can be accessed at you local USDA/NRCS or UC Cooperative Extension service offices.

Salinity is the salt concentration in water and soil and is measured by electrical conductivity (EC), commonly referred to as the EC in lab analyses (Western Fertilizer Handbook, 2002). Secondary treated municipal wastewaters can be high in salinity, depending on the source (Pettygrove and Asano, 1984). Salinity is one of the most important soil considerations in site selection because salts will continue to accumulate over time in direct proportion to the rate they are applied in the irrigation water. Salt accumulation over time can lead to soil physical problems limiting infiltration, soil chemistry problems limiting nutrient uptake, and impede the plants ability to osmotically absorb water.

The only practical way to reduce soil salinity is through leaching, that is applying water in greater amounts than crop water use to force the salts out of the root zone. The amount of water to accomplish leaching is called the leaching fraction. Leaching requirements can be calculated by comparing soil EC_e with water EC_w and are typically in the range of 10% to 20%. EC is measured in decisiemens per meter (dS/m = 1 mmho/cm). The typical range of soil EC_e for forage crop production is from 0.7 to 3.0 dS/m. Soil with EC_e values greater than 3.0 dS/m may take a considerable effort to produce a crop and the feasibility of farming these soils with reclaimed wastewater should be carefully considered.

The depth to the water table should be taken into account when determining leaching requirements and considering the suitability of a site for crop production. The long-term fate of the leachate must be considered. Soils with high water tables are not suitable for wastewater applications. The cropping history of the site may offer insight to its productivity and the potential for forage crop production. The climate of the site will significantly affect crop water use (ET) rates and cool season application rates. The topic of crop water use and cool season application rates will be discussed in more detail in later sections.

WASTEWATER CHARACTERISTICS

Irrigation with municipal effluent can be challenging compared to irrigating with other water sources. Nitrogen, as mentioned previously, is present in municipal effluent in concentrations that can be beneficial to plant growth but detrimental to the environment if it is not applied correctly. Other constituents of concern include salts, total dissolved solids (TDS), nutrients (P and K), sodium, chloride, boron, and bicarbonate. Heavy metals and pathogens also can be present in secondary municipal effluent. It is recommended that wastewaters be analyzed for heavy metals, as their accumulation in soil over time from repeated applications can have adverse effects on plant growth. Critical levels of heavy metals in wastewater can be found in Pettygrove and Asano (1984). The degree and content of these constituents depends largely on the source of the effluent. Wastewater may have different characteristics with respect to salinity and SAR compared to standard irrigation water. For a more thorough discussion of general soil and water quality as affected by salinity refer to Hanson et al. (1999).

The elements sodium, chloride, and boron that are contained in municipal effluent can accumulate over time in plants and soil and reduce yields. This problem is called specific ion toxicity. The accumulation of sodium in the soil from effluent applications can cause soil infiltration problems and exacerbate salinity problems (Pettygrove and Asano, 1984). The potential for infiltration problems to occur can be estimated in a lab analyses by calculating the soil Sodium Adsorption Ratio (SAR) and comparing it to soil EC_e. These values are outlined in the Western Fertilizer Handbook, 9th Ed., Table 2-5.

Nitrogen is the most significant constituent of concern in wastewater due to its potential to contaminate drinking water sources. Nitrogen exists in wastewater in several different forms. The four main forms of nitrogen (Table 1) in treated wastewater are nitrate (NO_3), ammonium (NH_4), nitrite (NO_2), and organic nitrogen. The two forms that are available to plants in the soil are nitrate (NO_3), and to a lesser degree ammonium (NH_4). The dominant form in treated effluent is organic nitrogen.

Table 1. Average nitrogen and total dissolved solid levels of wastewater from the Los Angeles County Sanitation Districts, Palmdale Water Reclamation Plant, located near Palmdale, CA. for 2002.

Constituent	Units	Max Value	Minimum Value	2002 Annual Average
Organic N	ppm	26.5	14.8	21.8
Ammonium (NH_4)	ppm	10.6	<0.01	2.97
Nitrate (NO_3)	ppm	0.45	0.03	0.18
Nitrite (NO_2)	ppm	0.83	0.01	0.24
Total Nitrogen	ppm	38.38	14.84	25.19
TDS	mg/L	723	469	644

Shortly after the application of wastewater to land, several conversion processes take place in the soil converting organic nitrogen and/or ammonium to nitrate. Mineralization is the conversion of organic nitrogen to ammonia (NH_3) and ammonium (NH_4). This process is followed by nitrification, which is the conversion of ammonium (NH_4) to nitrate (NO_3). At soil temperatures of 75^o nitrification may be completed in 1 to 2 weeks. At soil temperatures of 50© the nitrification process can take up to twelve weeks (Pettygrove and Asano, 1984). As a result of these processes, it is believed that most of the organic nitrogen will be converted to ammonium or nitrate and will be available to the plant during the growing season (Pettygrove and Asano, 1984). The rates of these processes are primarily dependent upon temperature, irrigation application amounts, soil aeration, soil type, and the level of organic matter.

Nitrogen can be lost in the system through denitrification and volatilization of ammonia. Ammonia (NH_3) loss rates through volatilization have been estimated at 20% or less in wastewaters with high ammonia concentrations (Pettygrove and Asano, 1984). If ammonium concentrations are low compared to the total nitrogen concentrations, then losses due to volatilization may be very low. Loss of nitrogen through denitrification has been estimated at 10% to 20% for sandy loam and loam soils with a medium denitrification potential, whereas well drained sandy soils have a very low potential of 5 to 10% (Pettygrove, personal comm. 2004).

MANAGING CROP WATER AND NUTRIENT USE

Nitrogen applied through wastewater to cropland is either taken up by the crop, leached beyond the crop root zone, resides in the soil, or is lost through denitrification or volatilization. To minimize the potential of groundwater degradation, it is critical to balance crop water and nutrient demand with what is applied in the wastewater. To accomplish this one must document crop yield, the amount of water applied, the amount of water consumed by the crop (ETc), the nutrient content of the water (N, P, and K in a water analysis), and the nutrient content of the crop (in a tissue analysis).

Water Application Balance (Crop Water Use ETc vs. Applied Water)

The amount of irrigation water that should be applied to any given crop is dependent upon fluctuating seasonal crop water use patterns. Evapotranspiration (ET) is a term used to describe the amount of water both used by a plant and evaporated from the soil surface. ET is most affected by solar radiation, temperature, humidity, and wind. ET rates are used as an estimate of crop water use and are expressed in inches. Due to variation in crop growth and development at different times of the year, the "reference crop or potential ETo" is usually multiplied by a crop coefficient (Kc) to obtain the actual forage crop ETc. This information can be accessed through UC publications, at UC Cooperative Extension County Offices, or on the internet at www.cimis.water.ca.gov.

A water balance basically compares the amount of wastewater applied through the irrigation system to the crop water use ETc within a given amount of time. For measuring the amount of wastewater applied through the irrigation system it is important to have a flow meter installed. Flow meters are typically placed near the mainline water source and they measure water application rates in acre-inches per hour or cubic feet per seconds. It is best to conduct water balances on a monthly basis to detect over applications in a timely manner. The amount of water applied above ET is called the leaching fraction. Irrigation applications are termed "deficit" when the applied water is less than crop water use ET. Most center pivot, flood, and hand line irrigation systems designed for wastewater reuse are only 70% to 85% efficient. The overall irrigation requirement takes into account the crop water use (ETc), the leaching requirement (depending on water and soil salinity), and the irrigation efficiency.

Sometimes keeping track of ET data can be cumbersome and it can be difficult to obtain accurate data depending on where you are located in California. Monitoring soil moisture can be a more reliable and easier method for estimating wastewater movement through the soil and simpler than using ET data. The use of electrical resistance blocks is popular, inexpensive, and relatively easy to use for monitoring soil moisture at different depths. Sensors can be read by a hand held meter or an electronic data logging device for more accurate and easier data collection. In alfalfa the sensors should be placed at 12, 24, and 48-inch depths in the field. A deeper sensor at 5 or 6 feet may be warranted on well-drained soils where flood irrigation is practiced. The 12 and 24 inch sensors should be used to schedule irrigations while the 48 inch sensor illustrates activity of water below the root zone. Moist soil conditions below 4 feet or below can indicate over-irrigation.

Nitrogen Application Balance (Crop Demand vs. Nitrogen Applied in Wastewater)

Total nitrogen can be present in wastewater in concentrations ranging from 5 ppm to 40 ppm (Page et al., 1983; Pettygrove and Asano, 1984). This could potentially result in nitrogen application rates of 13.5 lbs N to 108 lbs N in one acre-foot of applied wastewater. Although water and nutrient use rates can be high for certain perennial forage crops such as alfalfa, wastewater that contains nitrogen concentrations in excess of 30 ppm could be more than certain crops could consume (Tables 2 and 4). Although phosphorus (P) and potassium (K) are important to plant growth and should be considered in wastewater applications, general application concepts of these nutrients are similar to that of nitrogen. Of these elements phosphorus is more important to the growth and development of alfalfa and should be considered in the water analysis and nutrient balance. Because nitrogen is the main nutrient of environmental concern in wastewater applications, this report will focus on nitrogen applied in the wastewater.

Table 2. Summary of crop water use (ETc), crop nutrient uptake rates, and salinity thresholds for various forage crops grown in the high desert areas of Southern California.

	Crop Water Use ETc	Crop Uptake[2] (lbs/ton)			Salinity Tolerance[3]	
Crop	**Normal Year ET[1] Victorville, Ca. (Ac.ft.)**	**N**	**P_2O_5**	**K_2O**	**Soil EC_e**	**Water EC_w**
Alfalfa	**6.56**	**56**	**15**	**60**	**2.0**	**1.3**
Bermudagrass	**4.60**	**50**	**12**	**47**	**6.9**	**4.6**
Sorghum-Sudan	**3.30**	**41**	**16**	**59**	**2.8**	**1.9**
Corn silage	**2.30**	**8.3**	**3.6**	**8.3**	**1.8**	**1.2**
Winter forage	**2.40**	**40**	**--**	**--**	**6.0**	**4.0**

[1]Source of crop water use (ETc) rates for the high desert were based on values from Victorville CIMIS weather station number 117. Figures assume 80% irrigation efficiency.

[2]Crop nutrient uptake rates were adapted from the Western Fertilizer Handbook, 9th Ed., Table 4-1.

[3]Salinity tolerance values were adapted from two sources:
1.) Western Fertilizer Handbook, 9th Edition, Table 2-10.
2.) B. Hanson et al., 1999. Agricultural Salinity and Drainage. DANR Publication 3375. Table 2, p. 13.

Due to losses from volatilization and denitrification, only a certain portion of the nitrogen applied in the wastewater will be available to the plant. In a nitrogen balance the Plant Available Nitrogen (PAN) is typically compared to the nitrogen actually used by the crop. Calculations are outlined as follows:

Calculating Plant Available Nitrogen (PAN) Applied in Wastewater

Assumptions:

1.) lbs N per Acre Foot of wastewater = mg/L (ppm) of N in the water analysis x 2.72
(there are 2.72 million lbs in one Acre Foot of water).

Table 3. Determining PAN from a wastewater nitrogen analysis.

Nitrogen form	Units	Amount in Wastewater	Plant Available Nitrogen (PAN)	Notes:
Organic N	ppm	21.8	21.8	
Ammonium (NH_4)	ppm	2.97	2.97	Losses to NH_4 vol. are insignificant[1]
Nitrate (NO_3)	ppm	0.18	0.18	
Nitrite (NO_2)	ppm	0.24	0.24	
Total Nitrogen	ppm	25.19	**23.94 ppm PAN**	5% denitrification loss[1]

[1]In this case wastewater ammonium concentrations are so low that losses due to ammonia volatilization would be negligible. In well-drained sandy soils common to this site, losses to denitrification could be assumed to be 5-10% (Stuart Pettygrove, personal comm. 2004).

Total PAN Applied (lbs/ac) = Effluent PAN (ppm) * 2.72 (million lbs/ac-ft) * Applied Water (ac-ft/ac)

23.94 ppm PAN x 2.72 million lbs water per Acre Foot **=** ***65.11 lbs Plant Available N applied per Acre Foot of wastewater***

If Crop Water Use (ETc) (from Table 4) **= 6.56 Acre Feet per year x 66.5 lbs PAN**
= ***427 lbs Total N applied in the wastewater***

This amount of nitrogen application would require an annual alfalfa yield of 7.8 tons per acre to consume all of the nitrogen applied through the wastewater.

Amount of Nitrogen Consumed by the Crop

(N Consumed by Crop (lbs/ac) = Crop N% * Yield

Assumptions:

1.) **% Nitrogen in crop plant tissue = 16% of Crude Protein in tissue analysis.**
    a. **If CP of alfalfa = 21%, then % N alfalfa tissue = 3.4%**
2.) **Typical N% for alfalfa ranges from 3.0% to 4.0% Nitrogen.**
3.) **Typical N% for cereal forage ranges from 1.4% to 2.0% Nitrogen.**
4.) **Knowledge of crop yield in tons per acre is required to calculate crop N consumption.**
5.) **1 Ton = 2,000 lbs**

EXAMPLE: NITROGEN USE FOR GROWING ALFALFA AND CEREAL FORAGE

Alfalfa Yield = 8 tons per acre/year x (2000 lbs/ton) x (.035 N% alfalfa tissue) **=** ***560 lbs N used per year in the alfalfa crop***

Cereal Forage Yield = 3 tons per acre/year x (2,000 lbs/ton) x (.020 N% cereal tissue) = ***120 lbs N used in the cereal forage crop***

If ammonium concentrations of the wastewater are low in proportion to the total nitrogen concentration in the wastewater, then losses due to volatilization are typically negligible (Pettygrove, personal comm. 2004). In the example above, the amount of PAN applied in the wastewater was 427 lbs per acre and the amount utilized by the alfalfa crop was 560 lbs per acre. So with an alfalfa yield of 8 tons per acre there is complete utilization of the nitrogen applied in the wastewater. However, with 5 tons of alfalfa production there would only be a utilization of 350 lbs of the nitrogen applied. So it is imperative to produce adequate crop yields to completely utilize the nitrogen applied in the effluent. To summarize this concept, Table 4 outlines nitrogen utilization of different crops with crop yields and water use rates common to the high desert areas of Southern California.

Table 4. Summary of the calculations used above to show the surplus or deficit of the nitrogen applied in municipal effluent to forage crops in the high desert of Southern California near Lancaster, California.

Crop	**ETc Lancaster[1] (Ac.ft.)**	**Nitrogen Uptake[1] (lbs/ton)**	**Crop Yield, Lancaster (tons/ac.)**	**Applied Nitrogen in Effluent[2] (lbs/ac)**	**Crop Nitrogen Uptake[3] (lbs N/Acre)**	**Nitrogen Surplus or Deficit[4] (lbs N /acre)**
Alfalfa	6.56	56	8	426	448	- 22
Bermudagrass	4.60	50	6	299	300	- 1
Sorghum-Sudan	3.30	41	7	214	287	- 72
Corn silage	2.30	8	27	150	224	- 74
Winter forage	2.41	40	4	157	160	- 3

[1]Crop water use (ETc) rates and nitrogen uptake values were adapted from Table 2.

[2]Applied nitrogen in effluent represents 65 lbs per acre (calculated from 23.9 ppm PAN (Table 3) in effluent x 2.72 million lbs water/ac ft) x crop water use ETc).

[3]Crop nitrogen uptake was calculated by nitrogen uptake (lbs N/ton) x crop yield (tons/acre).

[4]The nitrogen surplus (+) is when the amount of nitrogen applied in the effluent is greater than crop uptake, while the deficit (-) is when the amount of nitrogen taken up by the crop is greater than that applied in the effluent.

Notice the deficit of nitrogen applied in the effluent for all of the crops in Table 4. It is important to point out that these nitrogen use values can only be realized with adequate crop yields outlined here. Thus it is imperative for wastewater reuse operations to maximize crop productivity to utilize the nutrients applied in the wastewater. When planning a wastewater reuse operation, considerations such as the nutrient load applied in the wastewater and typical crop yield averages should be compared. Plant sampling for total nitrogen at harvest and sampling the soil for residual NO3-N should complete final verification of the assumed nitrogen uptake by the crop. Table 5 outlines residual nitrogen remaining in the soil profile in a wastewater reuse system with 14 years of application history.

Table 5. Results of soil analyses taken from 4 sites with different soil types on Gene Nebeckers' farm near Lancaster CA., with a 14-year history of secondary treated municipal effluent applications to alfalfa and forage crops.

Site # and Description	Depth of Sample (feet)	Soil Nitrate (NO_3) (ppm)	Sodium Adsorption Ratio[1] (SAR)	Soil Nitrate-nitrogen[2] (NO_3-N) (ppm)
1. Loam	0.5 foot	26 ppm	6.41	5.87 ppm
1. Loam	1.5 foot	15 ppm	6.69	3.39 ppm
1. Loam	3.5 foot	13 ppm	6.37	2.93 ppm
2. Silt/Clay	0.5 foot	24 ppm	8.59	5.42 ppm
2. Silt/Clay	1.5 foot	22 ppm	8.22	4.97 ppm
2. Silt/Clay	3.5 foot	15 ppm	8.54	3.39 ppm
3. Sandy	0.5 foot	17 ppm	7.13	3.84 ppm
3. Sandy	1.5 foot	12 ppm	8.52	2.71 ppm
3. Sandy	3.5 foot	12 ppm	7.85	2.71 ppm
3. Sandy	6.5 foot	13 ppm	10.76	2.93 ppm
4. Silt/Sand	0.5 foot	17 ppm	6.79	3.84 ppm
4. Silt/Sand	1.5 foot	22 ppm	10.33	4.97 ppm
4. Silt/Sand	3.5 foot	12 ppm	4.80	2.71 ppm

[1]SAR adequate range would be 8-12 in these soils, given the water EC_w is approximately 0.8 to 1.0.

[2] Soil nitrate-nitrogen (NO_3-N) was calculated from soil nitrate (0.226 x soil NO_3 (nitrate)).

Typical soil NO_3-N levels are in the range of 4 to 6 ppm in alfalfa fields in the high desert areas of Southern California (Tim Hays, personal comm., 2004). These soil analyses values are within the optimal range of soil for alfalfa in the high desert. Most of the nitrogen (3.8 to 5.8 ppm) is in the top 0.5 feet, while deeper depths are lower in nitrate concentrations (2.7 ppm to 3.3 ppm). The higher concentrations in the upper depths are more than likely due to the addition of nitrogen in the wastwater while the lower concentrations of NO_3-N at the deeper depths illustrates the efficient nitrogen use of the alfalfa crop throughout the root zone.

OTHER CROP PRODUCTION CONSIDERATIONS

The main objective of any wastewater reuse project should be to maximize yields and utilize waste resources with the greatest efficiency, safety, and sustainability. While planning a wastewater application project there are several important factors to consider in addition to the issue of nutrient balance. These include the irrigation system, crop selection, farm management practices, and relations between the farmer and entity supplying the wastewater.

Irrigation systems used to grow forage crops in California include flood, wheel or solid set sprinklers, and center pivot systems. Of these systems, center pivots are typically the most efficient at 75-85%, but these systems need soils with relative high infiltration rates to operate without excessive runoff. Center pivot irrigation systems often require frequent cleaning of the nozzles and a filter system designed for irrigating with reclaimed water. In heavy clay soils flood irrigation systems may be sufficient, but may require more intensive management to get uniform applications. With tail water return systems and the right soil type, irrigation uniformities of 85% to 90% have been achieved with this type of border irrigation in evaluations in Kern County (Blake Sanden, personal communication). Typical uniformity/efficiency is 70% to 80%. Sprinkler irrigation systems in the form of solid set hand move lines or wheel lines are very common in the state and have an efficiency of 65% to 85%. Chemigation with wastewater should be carefully considered since it is suspected that the organic constituents in the wastewater break down pesticides. Therefore chemigation with wastewater is not recommended.

With regards to the selection of forage crops, alfalfa can be the highest consumer of water and nutrients, especially nitrogen (see Table 2). Contrary to popular belief, alfalfa can consume nitrogen in excess of 800 lbs per acre. In fact, alfalfa is currently being used at nitrogen pollution sites to remediate nitrogen-contaminated soil (Russelle et al., 2001). Many people have misconceptions that nitrogen use by alfalfa is low because it has the ability to produce its own nitrogen to satisfy its production needs through nitrogen fixation with *rhizobia* bacteria in the soil. However, many researchers believe that alfalfa will consume nitrogen preferentially, meaning it will utilize free soil nitrogen before fulfilling the rest of its nitrogen requirements through nitrogen fixation. In studies conducted by Meyer (1984), nitrogen was applied to alfalfa at rates as high as 1200 lbs per acre and resulted in no notable increase in yield. Nitrogen requirements to produce an 8, 10, and 12 ton alfalfa crop have been estimated to be 480, 600, and 720 lbs N respectively without the addition of nitrogen fertilizer (Meyer, 1984). Furthermore alfalfa is a favorable crop for wastewater applications because it is a perennial that can remain planted for 3 to 10 years, depending on the variety and climate. Alfalfa is also a high water consumer (Table 2). Its water requirements in California have been estimated to be between 5.5 to 7.5 inches per ton of hay produced.

There are other production practices that need to be considered when using wastewater to irrigate forage crops compared to typical forage production systems. For example, weed control is typically more challenging because the nitrogen applied in the wastewater causes more weed growth. Another consideration involves application during the cool season. Although many waste facilities need to dispose of wastewater during the cool season, the crop may not be actively growing, depending on the climate. Crop demand for nutrients is directly related to the crop water use (ET) rates. Therefore winter applications should be carefully applied according to seasonal crop water use rates to properly utilize the nutrients applied in wastewater applications. Thus climate is a very important factor when planning a reuse project because provisions may need to be made to store excess wastewater during cooler temperatures when the crop is not actively growing.

History has proven that successful farming projects require a manager that has a vested interest in the operation as an incentive to produce profitable yields and quality. Skills required to maintain a farm are often underestimated by non-farming entities. The farmer must be allowed to make sufficient profit as an incentive to keep the operation sound. Past projects where the main intent was to "dispose" of the wastewater have often resulted in groundwater contamination from gross over application of effluent and no crop removal. The idea behind applying wastewater that contains nutrients to cropland is to remove the nutrients by removing the crop. Basically, the nutrients need to leave in the bales and not in the ground water!

For the project to be successful and environmentally sound it takes eager participation and cooperation on the part of the entity supplying the water, farm managers, and the agricultural consultants involved. The parties involved should have basic knowledge of soil, plant and water relationships as well as a balanced understanding of the economic, financial, and general management constraints in operating a productive farm. With sound agronomic management and proper application methods, treated effluent can be a useable water resource that can help conserve valuable "fresh" water resources for other more important uses, like slip'n'slides!

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