Crop Nitrogen Budgeting

(handout to accompany Module 5 of UCANR nitrogen management training)

Purpose of N Budgeting

Crop N budgets can be created at the regional, whole-farm, or field scale and for various purposes. This paper describes field-scale, seasonal N budgeting by growers and crop advisers. N budgeting at that scale has several purposes.

- To aid in planning N fertilization and to encourage a systematic approach to N management decisions
- As a tool for adaptive management and for long term tracking of crop N use efficiency
- To educate growers and crop advisers by drawing attention to on-farm resource use efficiency and potential off-farm impacts of N on environmental quality
- To provide data for use in USDA conservation plans and cost share programs
- To provide data for use in reports required under environmental regulations

Regarding the last point, since 2007, all milk cow dairies in the Central Valley have been subject to waste discharge requirements that include crop N budgets for individual fields. More recently, waste discharge requirements have been imposed on non-dairy farms in the Central Coast and Central Valley regions, and these also include N budgeting provisions. A discussion of these regulations and their N budget requirements is beyond the scope of this paper.

<u>What N budgets are not.</u> A field crop N budget is not a complicated computer model. Such models, used by researchers, often require inputs of data that are not readily available, such as soil hydraulic conductivity and microbial biomass; and they require extensive calibration. The N budgeting methods discussed in this paper are based on very simple models of the N cycle. This makes them more practical to use but less sensitive to the complexities of the real world. Informed judgment and agronomic knowledge are therefore required for their use.

Crop N Terminology

The terms used to describe the amount of N applied to land, taken up by crop plants, and removed in harvest can be confusing. Inconsistent use of such terms has complicated the debate in California over what growers should be required to report under recently adopted water quality regulations. Two such terms are **crop N requirement** and **crop N uptake.**

Crop N requirement, 1. amount of N plants must take up to achieve maximum yield. *The tomato crop must take up 240 lb N/acre to achieve maximum yield, so that is its N requirement.* **2.** amount of N that must be applied to land to achieve maximum yield. *You should apply 180 lb N/acre as fertilizer to the tomato crop. That is its N requirement.*

To add to the confusion, two other terms – **crop N demand** and **crop N need** – are used to for both senses of crop N requirement. All these terms are ambiguous and should not be used to refer to a specific quantity in a budget sheet, at least not without clarification.

Crop N uptake, amount of N taken up or absorbed by plants during a specified time period

Crop N uptake (also **crop N consumption** or **absorption**), in contrast to crop N requirement, is unambiguous; however, it is sometimes used interchangeably with the term **harvest N removal**, which is discussed below in the section on crop N use efficiency. The two terms (N uptake and harvest removal) are different, and for some crops they are very different. For example, processing tomatoes might take up 240 lb N/acre, but only 150 lb N/acre is removed from the field in the harvested crop.

Crop N uptake, unlike N harvest removal is difficult to measure. An unknown portion of N taken up by plants is lost during the season in sloughed roots, root exudates, pollen, senescing leaves, and as ammonia volatilized from leaves. Nitrogen harvest index (N harvested/total N uptake) can vary widely from below 50% for some vegetable crops to as much as 90% for silage corn and other forages.

N Budget Methods

There are several approaches to crop N budgeting. They all contain three elements:

(1) Crop N requirement, a general term that encompasses several more specific terms related to the amount of N needed to achieve acceptable crop yield and quality. This is sometimes referred to as the "sink" term in the budget and is in contrast to the source components of the budget. The sink and source here are roughly analogous to expenses and income in a financial budget.

(2) Non-fertilizer N credits and adjustments such as from irrigation water, manure, or cover crop residues, which are analogous to income on investments and other irregular or one-time sources

(3) Fertilizer N, also a source. It is almost always set as the "closing term" in the budget, which means that it is calculated as the difference between crop N requirement and the non-fertilizer N credits and adjustments.

We describe six different approaches in this paper, each named after its sink (crop N requirement) term. The N source and sink terms are summarized in Table 1, and advantages and limitations of each are shown in Table 2. Further comments are provided next.

Method 1 – Budget based on typical grower N rate

In this approach, the crop N requirement term is selected from within the range of N application rates used by growers in the local area. In the hypothetical lettuce example shown in **Fig. 1**, crop N requirement is set at the midpoint of the "typical grower range"; then the fertilizer N application rate is adjusted downward from that point based on credits or adjustments from various non-fertilizer sources. Following are comments on some of these sources:

- Nitrate in irrigation water
  We can estimate N in the irrigation water by the simple formula

  N in irrigation water (lb N/acre) =
  NO_3-N concentration (ppm) x amount of irrigation water applied (inches) x 0.227

  where 0.227 is a conversion factor specific to these units.

  It is recommended here that crop evapotranspiration (ET_c) be used in place of irrigation water actually applied. Crops are usually irrigated with more water than is consumed by evapotranspiration. The reason for not counting the N in that extra irrigation water is that it will not be taken up by the crop. This makes a more realistic credit for what the crop is likely to obtain from the irrigation water. However, a result of this is that the grower may not be keeping track of all N applied. Evaluation of N use efficiency requires accounting of all N inputs uncorrected by an efficiency or recovery factor. When we discuss crop N use efficiency later in this paper, we will come back to this point.

- N mineralized from the preceding crop residues
  This budgeting method assumes that typical grower fertilizer N rates already take into account the N effects of previous crop residues and soil organic matter. However, where the preceding crop leaves an atypically large amount of high-N residue, a credit for this should be included in the budget. Examples of unusually high N crop residues for the lettuce example are alfalfa, broccoli, or high biomass legume or legume/grass cover crops.

  The amount of N credit to allow in the budget for preceding crop residues is not well formulated. Estimates of availability of N in crop residues based on residue N content are provided in Table 3. A suggested credit to crops following alfalfa is 40-60 lb N/acre (Pettygrove and Putnam, 2009).

- N mineralized from applied manure
  In this method, a credit for plant-available N (PAN) from manure and other organic materials should be included. (In the lettuce example in Fig. 2, there is no manure applied, but if there had been, a credit would have been included.) For guidance on N content and N mineralization values for manure and other organic materials, see Andrews and Foster (2005), Sullivan, (2008), Hartz and Mikkelsen (2008), Pettygrove et. al (2009), and Pettygrove et al. 2009.

  Where the material applied is mature compost or weathered corral manure, the N credit will be small, possibly negligible, even though the total amount of N added is significant.

  N credits for manure applications are at best, an educated guess. If the material has not yet been applied, growers will likely not have a reliable estimate of the application rate or the N content and N availability. However, if organic amendment applications are completely ignored in the planning budget, there is a risk of overestimating the planned N fertilizer need.

<u>Advantages of Method 1:</u>

Compared to other crop N budgeting methods, Method 1 is closer to the way that growers and crop advisers actually think about fertilizer N application rates, i.e., they consider what the typical local practice is and then make adjustments to that based on site-specific conditions and production goals.

<u>Limitations of Method 1:</u>

There may not be reliable information on typical grower fertilizer N practices, and bias can easily intrude. Representative surveys of grower N rates are lacking for most crops in California. For some crops, fertilizer rates shown in UC Davis Sample Cost & Return Studies (coststudies.ucdavis.edu) can be used, though in some cases, these are based on a very small sample of growers; and in any case, these studies do not provide a range of N rates that is useful for this budgeting method.

Another problem with Approach 1 is that the typical range of N rates, especially the upper end, may for some crops be much higher than university recommendations or any rational assessment of crop need would suggest. Use of very high N rates may reflect aggressive pursuit of high yields by growers. Or it may be based on the attitude “Don’t mess with success” and resistance to scrutinizing practices that have long been standard. Some growers may apply very high fertilizer N rates to compensate for high N leaching losses that result from sub-standard irrigation system performance or poor fertilizer application timing.

Method 2. Budget based on yield goal and fertilizer N rate field experiments (example: UC recommendation for cotton)

In this method, the crop N requirement is set at a value determined by field experiments with a range of fertilizer N rates applied. In the cotton example shown in **Fig. 2**, we use the UC recommendation of 45-55 lb available N for each bale of yield goal. This is based on research by Fritschi et al. and is a slight reduction from available N per bale recommended in the UC Cotton Production Manual (Hake et al., 1996 and summarized online by the California Department of Food & Agriculture, apps.cdfa.ca.gov/frep/docs/Guidelines.html).

Comments on some of the features of this method:

- Yield goal
  In the example (Fig. 2), the yield target is 3.5 bales. Multiplying that by 50 lb N/bale (the midpoint of the UC recommended 45-55 lb N/acre) gives a crop N requirement of 175 lb N/acre. An important question for all budgeting methods that involve a crop yield target is, should the grower use a realistic yield, such as average yield over the past 3 to 5 crops? Or only the top yields where there is a much better chance for profit? In most, though not all, irrigated crops in California, there are one of more opportunities to apply N post-emergence through the irrigation system or as sidedressing. Except where there is no further opportunity after planting to apply N, realistic, rather than “top” yield goals should be used in planning budgets.
- Soil nitrate
  Available N with this method includes soil nitrate measured in the spring – the closer to planting, the better. Cotton can effectively use soil nitrate to a depth of several feet. This is due to the fact that in the San Joaquin Valley, cotton is usually grown on clayey soils and because it has a deep tap root. The current UC recommendation is to collect a soil sample for nitrate to a 2-ft depth (R. Hutmacher, personal communication). The 1996 UC Cotton Production Manual recommends sampling to a 3-ft depth. Sampling depth should be adjusted based on experience and local soil and leaching conditions. Soil nitrate is usually reported by analytical laboratories as concentration in parts per million (ppm) or milligrams per kilogram (mg/kg) of nitrate-N. This can be converted to lb N/acre for a 12-inch sampling depth by multiplying by 4.

<u>Advantages of Method 2</u>

The advantage of this method is that it is easy to understand and is based on on-farm research in California, so it tends to represent “the real world”.

Limitations of Method 2

The limitation is that for many crops there is no UC recommended amount. Also, as the UC recommendation assumes "typical" contributions from crop residues and soil organic matter, the grower or adviser will need to make adjustments based on specific situations that differ from the typical.

Method 3. Budget based on amount of N per tree

The only example of this that we know of is a UC recommendation for oranges to apply 1 to 2 lb fertilizer N per tree. This recommendation is designed for oranges planted at the traditional spacing of 22 ft x 22 ft. In recent years, much closer spacings are being used, and it is not yet known how or even whether N rates should be adjusted for these closer spacings.

Method 4. Budget based on expected harvest N removal (example: UC recommendation for walnuts)

In this method, the crop N requirement is determined by multiplying a yield goal by the N content of the harvested product to obtain an estimate of N harvest removal in lb N/acre. The N content of harvested material can be obtained by analysis of samples collected by the grower, or, where that is not possible, by referring to literature values. For guidance on field methods for measurement of crop harvest nutrient removal, see Murrell (2008). For literature values of crop N content, see the IPNI website listed in the references. An example of the information from the IPNI website is shown in Table 4.

This budgeting method is the one recommended by UC for walnuts, almonds, and pistachios. For walnuts, UC recommends a crop N requirement of 40 lb N per ton of nuts to be harvested. In the example shown in **Fig. 3**, the target yield is 3 tons/acre which when multiplied by 40 lb N/ton gives an estimated harvest removal of 120 lb N/acre. **Caution: The harvest weight basis used by UC differs for these three nut crops: for walnuts and pistachios, it is nuts in the shell. For almonds, it is weight of kernels excluding shell and hull.**

Comments on Method 4.

This method as used for the UC walnut recommendation differs from the other budgeting methods described in this paper in that each N source, including fertilizer N to be applied is scaled down by an "N recovery factor". For fertilizer N, a low recovery factor (0.4) is recommended if the fertilizer is to be applied directly to the soil. A high recovery factor (0.8) is used if N is to be applied via fertigation.

Advantage of Method 4

The advantage of this method like Methods 2 and 3 is that it is based on on-farm research by UC under realistic field conditions.

Limitation to Method 4

A common objection to this approach is "I have to grow the whole plant, not just the part removed in the harvest". The rejoinder to that is that, at least in the case of almonds, walnuts, and pistachios, much of the N used to grow the shoots and leaves each spring ends up in the harvested nuts. Furthermore, the N that isn't harvested (the remaining N in leaves, hulls and any prunings) stays in the orchard and is used by the trees in future years.

However, recently, UC researchers (Patrick Brown lab) have modified the pure "harvest removal" approach to N budgeting for the tree nut crops by recommending that 20-40 lb N/acre (depending on tree age) be added to the harvest removal amount of N in order to account for the continued annual accrual of N in the tree structure. That update, however, is not shown in the budget sheet in Fig. 3.

Method 5. Based on harvest removal of N – Central Valley dairy version

This is the budgeting method required of Central Valley dairies under Waste Discharge Requirements (WDRs) that were implemented in 2007. This is a different version of the harvest N removal approach from that used in Method 4. The WDRs limit annual N applications (manure, dairy lagoon water, fertilizer, etc.) to 140-165% of crop N harvest removal, equivalent to a crop N recovery of applied N of 60-70%. Also, producers are required to report total N applied as manure and lagoon water, not just plant-available N.

Method 6. N budgets based on crop N uptake

This approach is similar to Approach 1, except that crop N uptake is used for the N sink term instead of typical grower N fertilizer rates.

A limitation of this approach – as discussed above in the crop N terminology section – is that there is no practical way for farmers to measure crop N uptake, and there are few published examples. Also, it is not clear which N source credits should be used, e.g., N from mineralization of soil organic matter. However, if better estimates of total seasonal N uptake were to become available in the future, crop N uptake might provide a useful measure of crop N requirement term in budgets.

Estimating N Use Efficiency (NUE)

Information in N balance sheets can be used to calculate **crop nitrogen use efficiency** or **NUE**. NUE is a general term and can be expressed in several ways. With some cautions, NUE can serve as an indirect indicator of the relative risk of nitrate leaching losses, which are difficult to directly measure. Also NUE can be used to compare different farms, fields, crop species or to assess the impact of changes in farming practices. For example, if a farmer replanted an orchard with a closer tree spacing and if both yield and N fertilizer use increased, it would be helpful to evaluate NUE in assessing the potential long-term impact on nitrate leaching.

A single year's NUE may be very misleading. NUE can fluctuate from year to year, and in a given year, a grower might harvest more N than was applied, resulting in a crop N recovery of >100%. NUE becomes more meaningful over a period of years.

For evaluating NUE in retrospect, it is important that values entered in N budgets during the planning phase be updated with actual amounts.

Expressions for Crop Nitrogen Use Efficiency (NUE)

There are multiple ways to express NUE. The most common expression is **partial nitrogen balance** or **PNB**. It is based on a simple view of a field as a box containing the crop and the root zone, with N entering the box as fertilizer, manure (and other organic amendments) and in irrigation water; and N leaving the box in the harvested crop. It is called a "partial" balance because it does not include N leaving the field as gas, in runoff or by leaching or entering the field from the atmosphere. Also it does not include N taken up by the crop that derives from sources inside the box, such as from mineralization of soil organic matter.

N uptake and N harvest removal are fairly clear in meaning, but are not the same. For many crops and situations, it is difficult to know total crop N uptake. The relationship of N uptake and harvest removal is described by N Harvest Index or NHI. Examples of uptake, harvest removal and NHI are shown in Tables 4 and 5. For many crops, though not all, N content is easily measured. For a discussion of methods of measuring nutrient removal, see Murrell (2008).

N harvest removal is the yield multiplied by N content of the harvested material. N removed in harvest includes N in all plant parts removed from the field, e.g., cotton lint, seed, and any additional trash. It does not include N in plant residues left in the field such as trimmings from field packed lettuce.

Example of calculation of PNB: A cotton crop receives 150 lb N/acre as fertilizer plus 25 lb N/acre as nitrate in the irrigation water for a total of 175 lb N/acre applied. The yield is 4 bales/acre. Based on a harvested crop N concentration of 32 lb N/bale (from the IPNI website – see references), the harvest removal of N is 4 bales/acre x 32 lb N/bale = 124 lb N/acre. Using only N harvest removal and N inputs, the PNB can be calculated in the following three ways:

Crop N recovery = 124/175 = 0.71, or 71%
Input to harvest ratio = 175/124 = 1.41 (unitless ratio)
Residual N = 175-124 = 51 lb N/acre

Alternative Expressions of NUE (Baliger et al., 2001 and Murrell, 2013)
Partial Factor Productivity (PFP) is the crop yield per unit nutrient applied. Example: In the US, from the late 1980s to 2010, the PFP increased from 0.80 to 1.20 bushels/lb N applied. This was due to increasing yields while fertilizer N rates stayed about the same. PFP is a useful measure of NUE where the rotation is limited to 1-2 crop species, and neighboring farms have the same rotation, as in the US Corn Belt. It is not as useful for comparing NUE where rotations are diverse and the desire is to compare NUE across many crop species.

Agronomic Efficiency (AE, also sometimes referred to as Agrophysiological Efficiency) is the yield increase per unit nutrient applied, where yield increase is the yield of a fertilized crop minus yield of an unfertilized crop. This method requires fertilizer check plots. It is useful for evaluating the economic return on fertilization.

Plant Physiological Efficiency (PPE) is the yield per unit of nutrient absorbed by the plant. This is useful for comparing crop varieties and assessing the effect of plant genotype on nutrient uptake.

Conclusions: Practicing the 4 R's in the Real World

N budgeting is a tool for planning crop nutrient management and for focusing grower attention on the sources and fates of N in the environment. Budgets, if updated with actual amounts of N applied and harvested, provide the records needed for calculating crop N use efficiency (NUE). NUE can serve as an indirect indicator of the nitrate contamination of surface and groundwater.

Care must be taken that N budgeting, with its singular focus on the total seasonal amount of N applied per acre, does not distract from the other three critical fertilizer “R”s: Right timing, Right placement, and Right material. Conservative pre-season N applications followed by soil nitrate testing and plant tissue analysis to decide whether to apply more after crop establishment or late in the season. This is especially true for tree fruits and nuts. Leaf analysis is a very important tool for managing N in these crops, and its use by farmers is well-established.

Furthermore, the root causes of low crop recovery of N often are inadequate irrigation system performance, misuse of manures and other recycled wastes, and weak soil and plant monitoring programs (Letey and Vaughan, 2013). Poorly maintained or calibrated equipment (fertilizer injectors and applicators, manure spreaders) and poorly operated surface irrigation water-run fertilizer applications can render N budgeting irrelevant.

References and Other Resources

N budgeting concepts, methods, definitions

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Table 1. Summary of approaches to crop N budgeting: Crop N requirement and N source terms.

Crop N requirement (sink) term	*Method 1* **Typical grower N rate**	*Method 2* **Based on yield, calibrated with fertilizer rate plots (UC example - cotton)**	*Method 3* **Recommended per tree (UC example - oranges)**	*Method 4* **N harvest removal (UC example - walnuts, almonds, pistachios)**	*Method 5* **N harvest removal (Central Valley waste discharge requirements for dairies)**	*Method 6* **Crop N uptake**
Non-fertilizer N credit or adjustment factor						
N in irrigation water	+	+	+	+	+	+
Plant-available N in manure/compost	+	+	+	+	--	+
Total N in manure/compost	--	--	--	where applied annually	+	--
Soil test nitrate	+	+	+	--	--	+
Cover crop N	+	?	?	+	--	+
N in preceding crop residue	+	?	?	--	--	+
Previous manure/compost - residual N	+	?	?	--	--	+
Yield target	?	+	--	+	+	?

+ = considered or could be considered, -- = normally not considered, ? = uncertain whether to include or depends on specific recommendation

Table 2. Summary of crop N budgeting approaches: Advantages and limitations.

Crop N requirement (sink) term	*Method 1* **Typical grower N rate**	*Method 2* **Based on yield, calibrated with fertilizer rate plots (UC example - cotton)**	*Method 3* **Recommended per tree (UC example - oranges)**	*Method 4* **N harvest removal (UC example - walnuts, almonds, pistachios)**	*Method 5* **N harvest removal (Central Valley waste discharge requirements for dairies)**	*Method 6* **Crop N uptake**
Advantages	Matches common grower approach	Based on CA research, simple, practical. Example: cotton	Based on CA research, simple, practical. Example: Oranges	UC recommended for almonds, walnuts, pistachios; research-based	Simple. Easy to calculate crop N use efficiency over years. Required of Central Valley dairies by regulation	Clear, precise expression of crop N need
Limitations	Typical grower N rates not known for some crops or span a very wide range. Grower rates are sometimes high in order to offset high NO_3 leaching losses.	Not available for many crops Basis for adjustments and credits often not specified in recommendation	Guidance available for any crops besides oranges? Basis for adjustments and credits not specified Not sensitive to yield goal	Yield for some tree crops not easy to forecast N removal per yield not always know Generic efficiency factors for inputs are to some degree arbitrary	Uses arbitrary loss factor Not well suited to long rotations or sporadic manure use Requires N analysis of harvested crop	Information not available for many crops in state; For some crops difficult to measure, not well-related to yield May require complete accounting of soil N inputs

Table 3. N mineralized during season from crop residues vs. N content of residue (drawn from Vigil and Kissel, 1991). Assumes ideal conditions of moisture and temperature.

Total N in residue (% dry wt.)	% of total N mineralized during in season*
0.5	*Immobilize*
1.0	*Nil*
1.5	14
2.0	25
2.5	34
3.0	41
3.5	47
4.0	52
4.5	57

Table 4. Sample information from the IPNI NuGIS website.

Nutrients Removed in Harvested Portion of Crop

Last Update: 10/28/2010

The values presented in the following table are estimates of nutrient removal or the quantity of nutrients removed in the harvested portion of the crop. They should not be confused with nutrient uptake which refers to the total nutrients absorbed by the growing crop. Tabular values are approximations based on the most recent information available to IPNI. Actual nutrient removal may vary by 30% or more depending on the specific growing conditions of the crop such as soil fertility level, yield, soil moisture, crop vigor, and limiting nutrients (interactions) as well as the actual crop variety and fertilizer program. Changes to soil fertility may differ from the amount removed by the crop. In some instances, weathering of soil minerals and organic matter may compensate for part of the nutrient removal by crops. In other instances, nutrients may be chemically fixed by the soil or lost by leaching, and the loss of nutrients will exceed crop removal.

Field Crops[2]	**Unit**	**N**	**P_2O_5**	**K_2O**
Barley (spring)	lb/bu	0.99	0.40	0.32
Canola	lb/bu	1.88	0.91	0.46
Corn (grain)	lb/bu	0.70	0.38	0.27
Corn (grain)	lb/cwt	1.25	0.68	0.48
Corn (silage, 67% water)	lb/ton	9.70	3.10	7.30
Cotton (lint)	lb/bale	32.00	14.00	19.00

Table 5. Examples of crop N uptake vs. N removed in harvested product. N harvest index is N removed in harvest divided by N uptake, expressed as %. (The values shown here are to illustrate the concept, and it should not be assumed that they are representative.)

	N uptake, lb/acre	N removed in harvest, lb/acre	N uptake minus harvest, lb/acre	N harvest index, %
Corn, grain	240	120	120	50%
Corn, silage	250	225	25	90%
Cotton	250	140	110	56%
Processing tomato	240	150	90	63%
Lettuce	140	70	70	50%
Strawberry	190	90	100	47%
Almond	224	204	20	91%

Also see: Crop Nitrogen Uptake and Partitioning. Available online at: http://apps.cdfa.ca.gov/frep/docs/N_Uptake.html

N BUDGET		LETTUCE, FIELD 40A	2014
			lb N/acre
Crop N Requirement			
Method used		Typical grower fertilizer N rates in region for this crop	
	1	Enter range of rates: 140-220	
	2	Midpoint of range	180
Non-fertilizer N inputs, credits, adjustments	3	N in irrigation water	30
	4	Recent crop residue/cover crop	20
	5	Past years' manure or compost	0
	6	This season's manure, compost, etc.	0
	7	Sum of lines 3-6, **Total non-fert N credits and adjustments**	50
Planned N fertilizer application	8	Line 2 minus Line 7 **Planned total fertilizer N applied**	140

Fig. 1. Hypothetical lettuce crop N budget based on "typical grower rate" (Method 1).

N BUDGET		Cotton, FIELD B 2014	
			lb N/acre
Crop N Requirement			
Method used	1	UC Recommended available N 45-55 lb N/bale	
	2	Yield target 3.5 bales/acre	
	3	Line 1 x Line 2 **Total required available N**	175
Non-fertilizer N inputs, credits, adjustments	4	N in irrigation water	20
	5	Soil test nitrate-N	52
	6	This season's manure, compost - available N	0
	7	Sum of lines 4-6, **Total non-fert N credits and adjustments**	72
Planned N fertilizer application	8	Line 3 minus Line 7 **Planned total fertilizer N applied**	103

Fig. 2. Hypothetical crop N budget based on N requirement determined by fertilizer rate field experiments (Method 2). Example here is based on UC cotton recommendations.

N BUDGET		Walnuts, Block 8B 2014	
			lb N/acre
Crop N Requirement			
Method used		Harvest removal	
	1	Yield = **3 tons/acre**	
	2	Line 1 x 40 lb N/ton = **Total N harvest removal**	120
Non-fertilizer N inputs, credits, adjustments	3	N in irrigation water applied x 0.7 (N recovery factor)	30
	4	N in cover crop x N recovery factor (0.5 if mowed or 0.7 if disked)	20
	5	N from manure or compost x %N released x 0.5 (N recovery factor)	0
	7	Sum of lines 3-6, **Total non-fert N credits and adjustments**	50
Planned N fertilizer application	8	Line 2 minus line 7 **Additional N needed**	70
	9	Line 8 divided by N recovery factor of 0.4 (or 0.8 for fertigation) **Planned total fertilizer N applied**	88

Fig. 3. Hypothetical crop N budget based on harvest N removal (Method 4). Example here is based on UC walnut recommendation.