University of California

Nitrogen Management Training

for Certified Crop Advisers

MODULE 5

Nitrogen Budgeting

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Purposes of Farm/Field-scale Crop N Budgeting

Looking ahead:

- Use as planning tool for crop management
- Encourages a systematic approach
- Educates and draws attention to potential environmental impacts
- Use for USDA conservation plans and cost share programs
- Provides data for use in reports required by environmental regulations

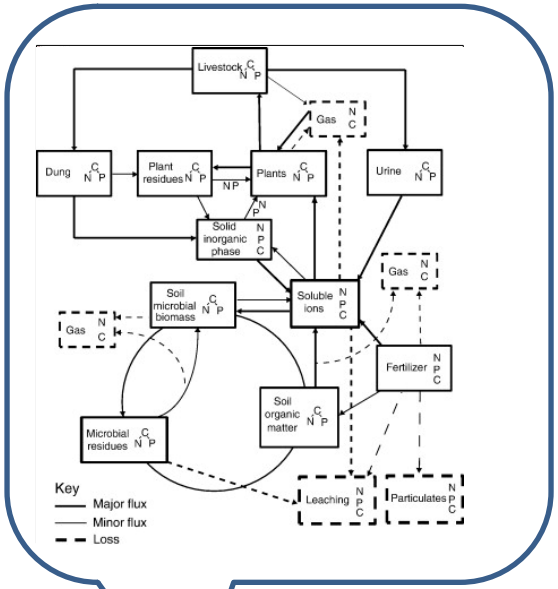
Purposes of Farm/Field-scale Crop N Budgeting

Looking back:

- Tool for adaptive management: What is working? What needs to be changed?
- Long-term tracking of crop N use efficiency
- Data supplier for reports required under environmental regulations

What N Budgeting is NOT

Input:
"How much N is needed for 4 bale cotton in Fresno Co.?"



Output:
192.3 lb N/acre

Definitions

Crop N requirement, **1.** amount of N plants must take up to achieve maximum yield. **2.** amount of N that must be applied to land to achieve maximum yield.

Related terms: **crop N demand, crop N need**

Crop N uptake, amount of N taken up or absorbed by plants during a specified time period (also **crop N consumption** or **absorption**).

Related term: **crop N harvest removal**

Three elements of all N budgets

Sink term (expenses)

Crop N Requirement

		Typical range of fertilizer N rates in region for this crop	
	1	Lower end of range	140
	2	Upper end of range	220
Non-fertilizer N inputs, credits			
	3	N in irrigation water	30
	4	N mineralized from most recent crop residue, including any cover crop	50
	5	N mineralized from past year's manure or compost	0
	6	N mineralized from this season's planned manure or compost application	0
	7	Sum of lines 3-6, Total N inputs and credits, not including fertilizer	80
Planned N fertilizer application	8	Line 2 minus Line 7 Planned total fertilizer N applied	140

Three elements of all N budgets

Projected Crop N Requirement			
		Typical range of fertilizer N rates in region for this crop	
	1	Lower end of range	140
	2	Upper end of range	220
		irrigation water	30
		ineralized from most recent crop residue, including any cover	50
		ineralized from past year's manure or compost	0
		ineralized from this season's planned manure or compost ication	0
	7	Sum of lines 3-6, Total N inputs and credits, not including fertilizer	80
Planned N fertilizer application	8	Line 2 minus Line 7 Planned total fertilizer N applied	140

Non-fertilizer credits and adjustments

Source terms (interest income, one-time inputs, etc.)

Three elements of all N budgets

Projected Crop N Requirement			
		Typical range of fertilizer N rates in region for this crop	
	1	Lower end of range	140
	2	Upper end of range	220
Non-fertilizer N inputs, credits			
	3	N in irrigation water	30
	4	N mineralized from most recent crop residue, including any cover crop	50
	5	N mineralized from past year's manure or compost	0
	6	N mineralized from this season's planned manure or compost application	0
	7	Sum of lines 3-6, Total N inputs and credits, not including fertilizer	80
		Line 2 minus Line 7	140

N fertilizer application

Closing source term (additional income required)

Nitrogen Budgeting Methods

N Budgeting Methods

Method	Basis for N requirement
Method 1	Typical grower rates
Method 2	UC recommended (yield based)
Method 3	UC recommended (per tree)
Method 4	N harvest removal –tree nuts
Method 5	N harvest removal - dairy
Method 6	Crop N uptake

Nitrogen Budgeting Methods:
Method 1, Typical Grower Rates

N Budgeting Method 1 Typical grower rate

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**	130

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**	130

N Budgeting Method 1 Typical grower rate example

Assumption:
The grower N rate takes into account typical N losses and typical contributions of N from soil organic matter and crop residues.

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**	130

N Budgeting Method 1

Typical grower rate example cont'd.

lb N/acre = ppm N x inches of water* x 0.23

*For "inches of water" use crop ET, not actual applied.

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**	130

N Budgeting Method 1 Typical grower rate example cont'd.

N from the preceding crop residue

Count this where a large amount of N-rich residue has been incorporated.

Availability of N in Crop Residues

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

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**	130

N Budgeting Method 1

Typical grower rate example cont'd.

Plant-available N (PAN) from manure. See guidelines.

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**	130

N Budgeting Method 1

Typical grower rate example cont'd.

Conclusion:
In this case, fertilizing at low end of typical range poses low risk.

Nitrogen Budgeting Methods:
Method 2, UC Recommended
Based on Yield Target

N Budgeting Method 2

UC-recommended based on yield target

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

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

N Budgeting Method 2

UC-recommended based on yield target example

What is "yield target"?

- Past average yield for field?
- Hoped for yield?

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

N Budgeting Method 2

UC-recommended based on yield target example

Example:
Soil NO3-N
0-1 ft – 8 ppm
1-2 ft – 5 ppm
(Multiply by 4 at each 1-ft depth)

Soil NO3-N
0-1 ft – 32 lb/acre
1-2 ft – 20 lb/acre
Total: 52 lb/acre

Nitrogen Budgeting Methods:
Method 4, N Harvest Removal
(Tree Nuts)

Nitrogen Budgeting Worksheet for Walnuts

Name | **Date**

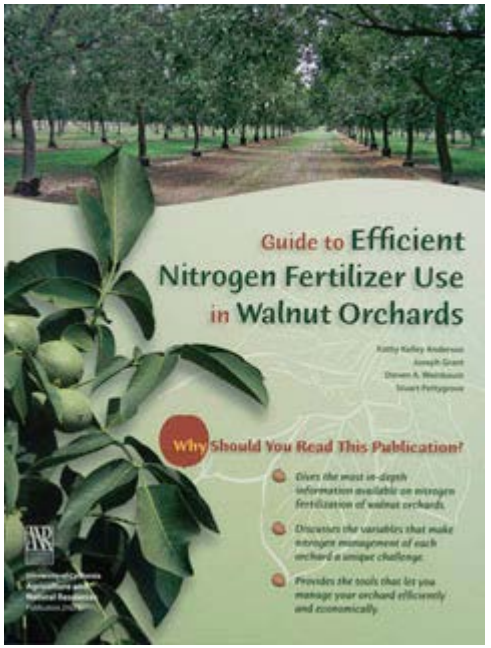
Block ID

1	**Nitrogen removed in the crop**	1a._____ x 40 (lb N/ton yield of walnuts) = Yield in tons of walnuts/acre	1._____lb N/acre lost in crop per year
2	**Nitrogen contributions from irrigation water**	If units are in NO_3-N ppm use line 2a; if units are NO_3 ppm use line 2b- not both. Put the result of line 2a or 2b on line 2c. 2a._____ x _____ x 2.7 = OR 2c._____lb N/acre x 0.7 = Estimated N recovery 2b._____ x _____ x 0.614 = NO_3 ppm or mg/l Water applied (ft)	2._____lb N/acre from irrigation water
3	**Nitrogen contributions from manure or compost**	If none applied, skip to line 4. 3a._____ x 3b._____ x 3c._____ x 0.5 x 0.2** = Tons/acre dry % N % N released* Estimated N recovery *For one-time applications use first-year release value from Section 1, Table 1. For annual applications, use 100% **Converts tons to pounds.	3._____lb N/acre from manure or compost
4	**Nitrogen contributions from cover crops**	If none, skip to line 5. 4a._____ x 4b._____ = lb N/orchard acre in cover crop Nitrogen recovery factor For mowing, use 0.5; For disking, use 0.7	4._____lb N/acre from cover crop
5	**Total nitrogen available from nonfertilizer sources**	Add lines 2, 3, and 4. Enter the result on line 5.	5._____lb N/acre
6	**Additional nitrogen needed**	To figure how much additional nitrogen is needed by your trees, subtract line 5 from line 1. Enter the result on line 6. If the answer is negative, no fertilizer is needed.	6._____lb N/acre needed by trees
7	**Nitrogen fertilizer application rate**	Divide the amount on line 6 by an estimated nitrogen recovery factor of 0.4 (or use a lower value, see instructions). Use 0.8 for fertigation. _____ ÷ _____ = lb fertilizer N/acre needed by trees (line 6) Estimated nitrogen recovery factor	7._____lb N/acre fertilizer rate

Note: Converting metric values for use in the table: 1 kg = 2.2 lb; 1 metric ton = 1.1 ton; 1 kg/T = 1.9 lb/ton; 1 kg/ha = 0.9 lb/ac; 1,000 m^3 = 1,556 acre-feet.

N Budgeting Method 4

N harvest removal



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

N Budgeting Method 4
N harvest removal example

Method ignores most of the N taken up by plant that is not removed in harvest.

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

N Budgeting Method 4
N harvest removal example

All N sources are multiplied by "N recovery factors".

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

N Budgeting Method 4
N harvest removal example

Even the calculated fertilizer N requirement is corrected by a "recovery factor"

Nutrients Removed in Harvested Crops

Estimates of nutrient removal in the harvested portion of crops. Actual nutrient removal may vary by 30% or more depending on growing conditions, crop variety, and fertilizer choice.

Field Crops	Unit	N	P_2O_5	K_2O
Barley	lb/bu	.99	.40	.32
Canola	lb/bu	1.88	.91	.46
Corn (grain)	lb/bu	.70	.38	.27
Corn (grain)	lb/cwt	1.25	.68	.48
Corn (silage, 67% water)	lb/ton	9.70	3.10	7.3
Cotton (lint)	lb/bale	32.00	14.00	19.00

(Values and descriptions from IPNI NuGIS)

Nutrient Uptake

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 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%

(Values and descriptions from IPNI NuGIS)

Methods Differ in How Non-recovery of N is Accounted

Method 1 – Typical grower N rate

Inefficiency built into crop N requirement

(but irrigation water NO3 – uses ET, not total)

Method 2 – Available N/unit yield (UC cotton recomm.)

Inefficiency built into crop N requirement

Method 4 – Harvest removal (UC walnut pub)

Inefficiency explicit as "N recovery factor"

N Budgeting Methods: Method 3

	Method	Basis for N requirement
☑	Method 1	Typical grower rates
☑	Method 2	UC recommended (yield based)
	Method 3	UC recommended (per tree)
☑	Method 4	N harvest removal –tree nuts
	Method 5	N harvest removal - dairy
	Method 6	Crop N uptake

N Budgeting Methods: Method 5

	Method	Basis for N requirement
☑	Method 1	Typical grower rates
☑	Method 2	UC recommended (yield based)
	Method 3	UC recommended (per tree)
☑	Method 4	N harvest removal –tree nuts
	Method 5	N harvest removal - dairy
	Method 6	Crop N uptake

N Budgeting Methods: Method 6

	Method	Basis for N requirement
☑	Method 1	Typical grower rates
☑	Method 2	UC recommended (yield based)
	Method 3	UC recommended (per tree)
☑	Method 4	N harvest removal –tree nuts
	Method 5	N harvest removal - dairy
	Method 6	Crop N uptake

Applying Nitrogen Budgeting Methods

Definitions:

Crop Nitrogen Use Efficiency (NUE)

- Measure of performance
- Allows comparison of fields, crop species, and farms
- Several ways to express it

Definitions: Expressions of NUE

Partial Nitrogen Balance (PNB) is the most common way NUE is expressed. Calculated with two numbers:

- Harvest N removal
- Sum of N inputs but ***only those from external sources*** (i.e., not from soil organic matter, residues, etc.)

Definition: Expressions of NUE Example

Partial Nitrogen Balance Sample Calculation

Cotton yield	3.5 bales/acre
N content of harvested lint + seed	32 lb N/bale* (source: IPNI)
Harvest N removal	112 lb N/acre (=3.5 x 32)
N fertilizer applied	180 lb N/acre

Definition: Expressions of NUE Example cont'd.

Partial Nitrogen Balance Sample Calculation

Eq. 1: Harvest N Removal/N Fertilizer Applied

$$\%\ crop\ recovery\ = \frac{112}{180} = \mathbf{62.2\%}$$

Eq. 2: N Fertilizer Applied/ Harvest N Removal

$$input{:}\ harvest\ ratio = \frac{180}{112} = \mathbf{1.61}$$

Definitions: Expressions of NUE

Partial factor productivity (PFP)

Yield/unit N applied

Example: bushels of corn/lb N applied

Definitions: Expressions of NUE

Agronomic Efficiency or Agrophysiological Efficiency (AE) is the yield increase per unit nutrient applied, where yield increase is yield of a fertilized crop minus yield of an unfertilized crop.

- Requires fertilizer check plots
- Useful for evaluating economic return on fertilization.

Definitions: Expressions of NUE

Plant Physiological Efficiency (PPE) is the yield per unit of nutrient absorbed by the plant.

- Use for comparing crop varieties
- Use for assessing effect of plant genotype on nutrient uptake.

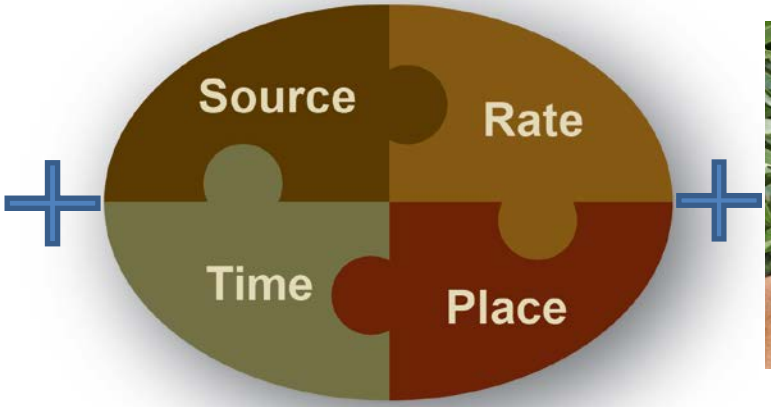
Which N Budget Method to Use

Situation	N budgeting method
Large client base, years of experience, mature set of production practices	Method 1 – Typical grower rate
Almonds, walnuts, pistachios	Method 4 – N harvest removal (UC recommended values)
Cotton	Method 2 – UC recommended available N per unit yield
All crops (regardless of budgeting method)	Measure/estimate and record • Total N for all external inputs • N harvest removal

N Budgeting Focuses on Only One of the 4Rs

To improve NUE: start with irrigation system performance, then look at the other 3 Rs. Finally, soil and plant tissue testing used to make mid-course corrections.

Irrigation System Performance



4Rs

Soil and plant tissue testing

References and Other Resources

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Nitrogen Management Training

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Course materials available at:

ciwr.ucanr.edu/NitrogenManagement

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California Department of Food & Agriculture (CDFA)
Fertilizer Research and Education Program
web: www.cdfa.ca.gov
Twitter: @CDFAnews

California Association of Pest Control Advisers (CAPCA)
web: capca.com

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