Nitrogen budgets in California rice systems:

What do we know and how can we improve?

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Outline

- Why is this important?
- Overview of inputs and losses
- NUE metrics
  - how it compares with global estimates
- **Where is surplus N going?**
- Where can we improve?

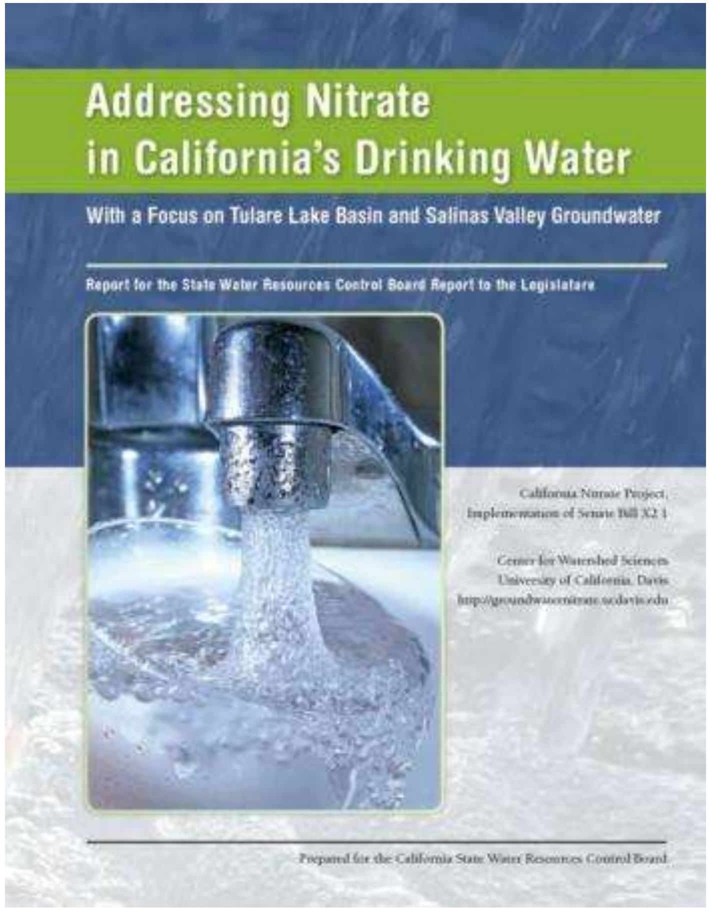
Why important?

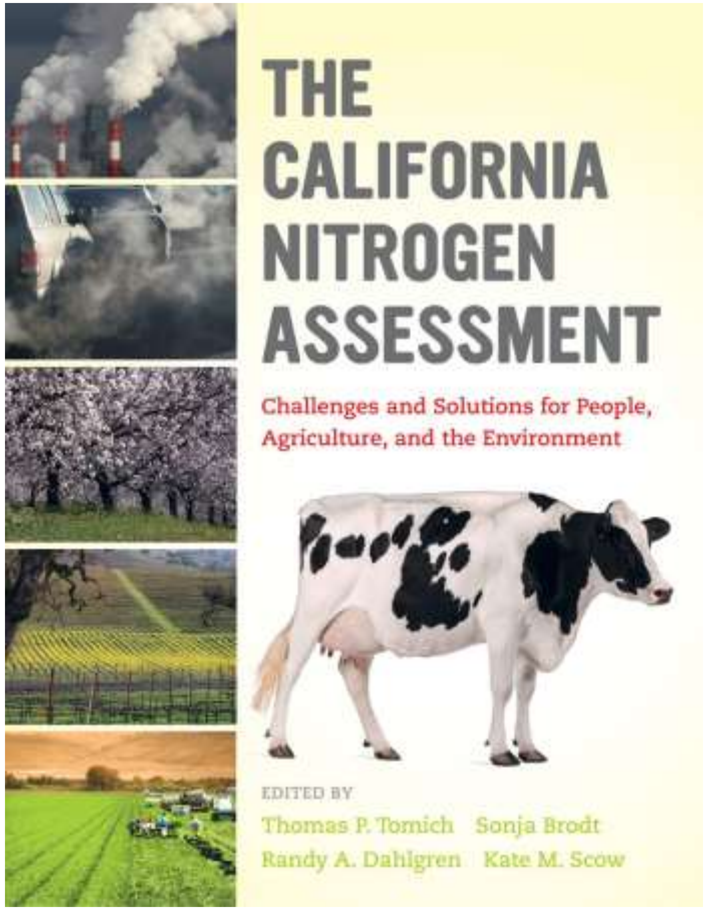
- Farm economics
    - Higher efficiencies can lead to higher incomes
- Excesses can lead to pollution
- Increasing regulation

Why important?

The Irrigated Lands Regulatory Program (ILRP) was initiated in 2003 to prevent agricultural runoff from impairing **surface waters**, and in 2012, **groundwater** regulations were added to the program.

Waste discharge requirements, which protect both surface water and groundwater, address irrigated agricultural discharges throughout the Central Valley.





Rice fields provide valuable waterfowl habitat for migrating birds along the Pacific Flyway.

At the end of January, fields are drained and allowed to dry.

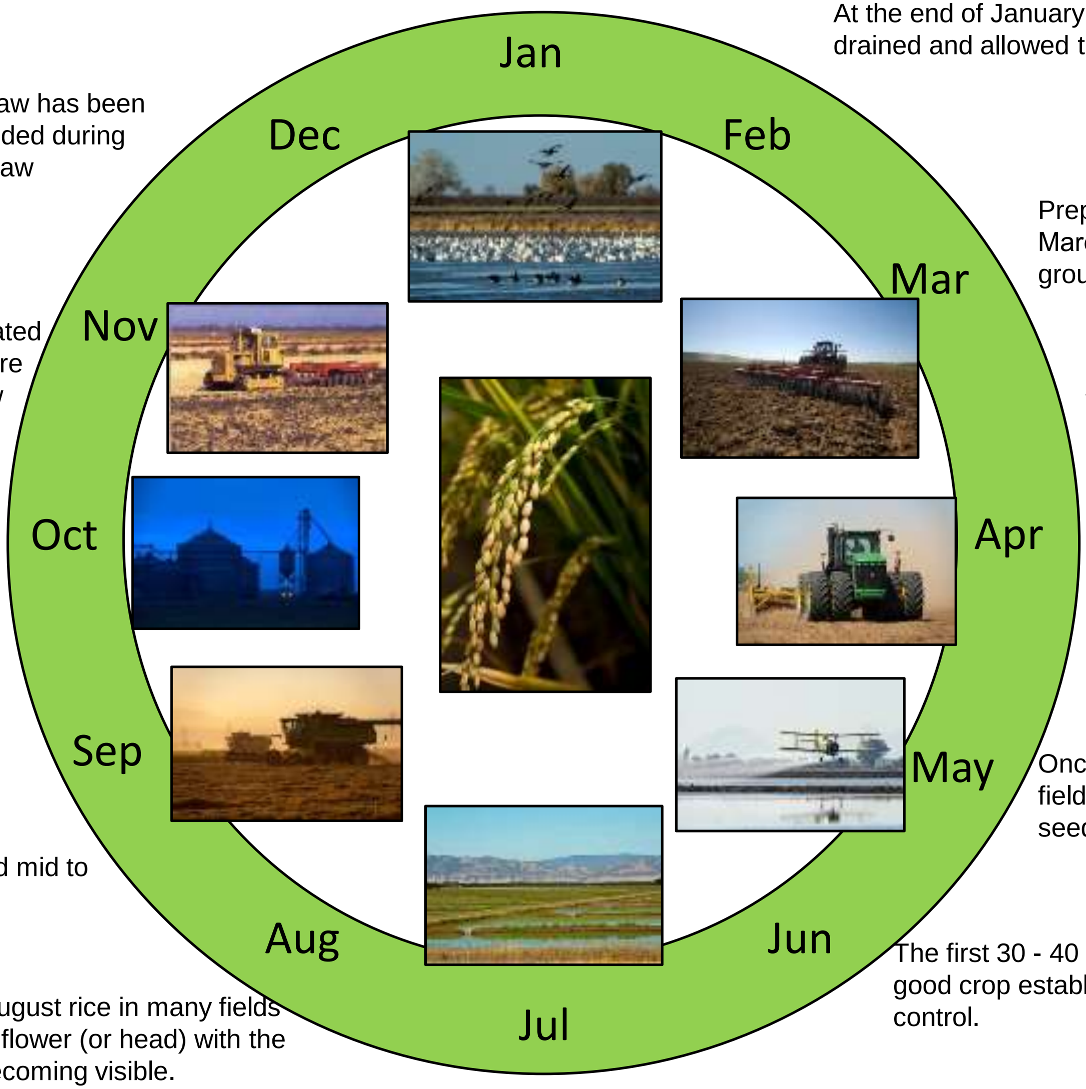
Preparing fields for planting begins in March by plowing to “open-up” the ground to facilitate faster drying.

Seed bed preparation begins in late March /early April using discs to break clods.

The final steps of seedbed preparation take place in late April/early May: fields are leveled, rolled and fertilizer applied.

Once the seedbed is ready, the fields are flooded and aerially seeded with presoaked rice seed.

The first 30 - 40 days the focus is good crop establishment and pest control.



By early August rice in many fields will start to flower (or head) with the panicles becoming visible.

Fields drained mid to late August.

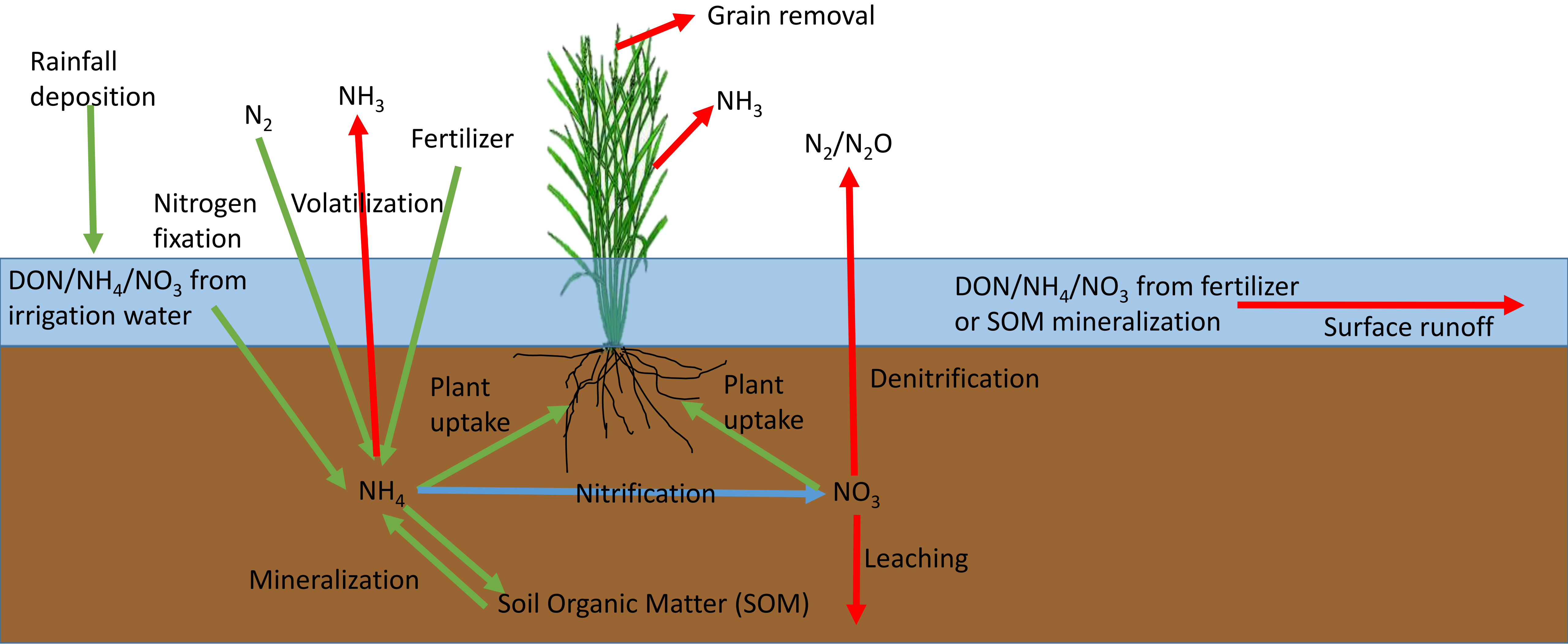
The crop is harvested in September and October.

Rice straw is generally incorporated into the field after harvest . If there are disease problems, rice straw may be burned.

Fields where rice straw has been incorporated are flooded during winter to facilitate straw decomposition.

Photos courtesy of California Rice Commission

Nitrogen cycle in rice systems



Nitrogen efficiencies

- Farm economics
  - Higher efficiencies can lead to higher incomes
- Excesses can lead to pollution

- Agronomic N Use Efficiency (ANUE)
  - Yield increase per unit of N applied
  - ANUE=$(\text{Yield}_{N+})-(\text{Yield}_{N0})/\text{N applied}_{N+}$
- N Recovery Efficiency (NRE)
  - % of fertilizer N taken up by crop
  - NRE=$(\text{Nup}_{N+})-(\text{Nup}_{N0})/\text{N applied}_{N+}$
- Partial Nutrient Budget (PNB)
  - PNB= Harvested N/N input
- N Use Efficiency-Total (NUE_T)
  - NUE_T = Harvested N/**N input**
  - N surplus= N input-harvested N

Explanation of data used for this study

- Quantifying N efficiencies (ANUE and NRE)
  - On-farm studies (Eagle et al., 2000; Linquist et al., 2006)
  - Farmer managed with N being applied by farmer (with exception of top-dress)
  - Used only treatments/sites that are typical of current management practices (i.e. N rates, winter fallow mgmt., water mgmt., etc)
  - 14 site/years total
- Quantification of inputs and outputs
  - Primarily studies conducted in CA
  - Some studies from outside literature

Agronomic N use efficiency

- Yield increase per unit of N applied
  - ANUE=(Yield$_{N+}$)-(Yield$_{N0}$)/N applied$_{N+}$
- CA average = 35 kg grain/kg N applied
- World average = 22 kg grain/kg N applied(Ladha et al., 2005)

Fertilizer recovery efficiency

- Percentage of fertilizer N taken up by crop
  - $NRE=(Nup_{N+})-(Nup_{N0})/N\ applied_{N+}$
- CA average = 58%
- World average = 46% (Ladha et al., 2005)

ANUE and NRE summary

- CA is doing very well by these metrics.
  - Most of the global studies originate from on-station studies
    - have higher efficiencies than on-farm studies.
- Why?
  - Incorporation of fertilizer N
  - Good water management

Partial N budget (PNB)

- Ratio of N in crop material exported from field to the amount of N fertilizer applied.
- Used for simplicity: harvested N/fertilizer N
- CA: 89%
  - Counts straw N as harvested N
  - Can be above 100% due to non-symbiotic N fixation

NUE_T and N surplus

- NUE_T = Harvested N/N input
- N surplus= N input-harvested N
- Annual basis

- N input
  - Includes all inputs
    - Fertilizer, deposition, irrigation water, N fixation (non-symbiotic)
- Harvested N
  - Only includes what is harvested and removed from field
    - **Only grain**
    - **Does not include residues if residues remain in the field**

Annual N inputs (kg N/ha)

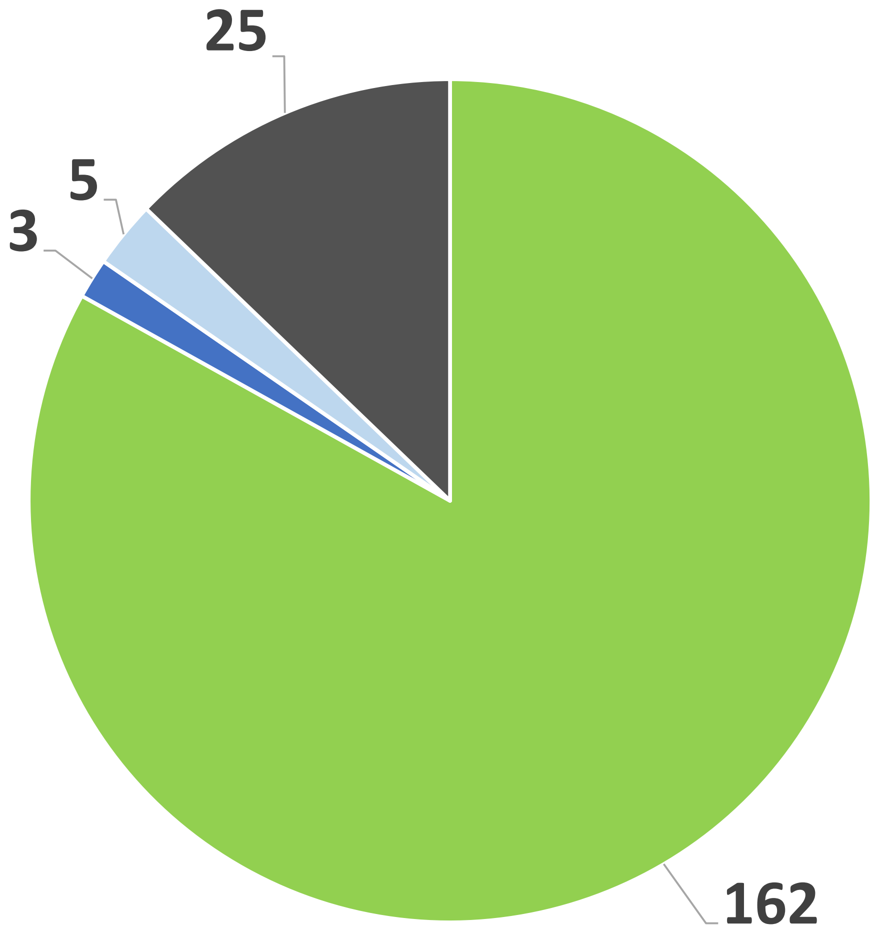
Total N inputs = 195 kg N/ha

(study average) ■ Fertilizer

(Linquist et al., 2014; Krupa et al., 2011) ■ Irrigation water (NO3+NH4+TON)

(Fink et al., 2010) ■ Rainfall

(Ladha et al., 2016) ■ N fixation



Harvested and NUE_T

- Yields averaged 10,790 kg N/ha
- Total N uptake: 167 kg N/ha
  - Straw N: 64 kg N/ha
  - **Harvested (grain) N: 102 kg N/ha**

- NUE_T = Harvested N/N input
  - 102/195 = **0.52**

Surplus N

- N surplus= N input-harvested N
  - 195-102 = **93 kg N/ha**

- **What happens to surplus N?**
  - **Particularly what ends up as reactive N**

What happens to surplus N? (kg N/ha)

Total Surplus N = 93 kg N/ha

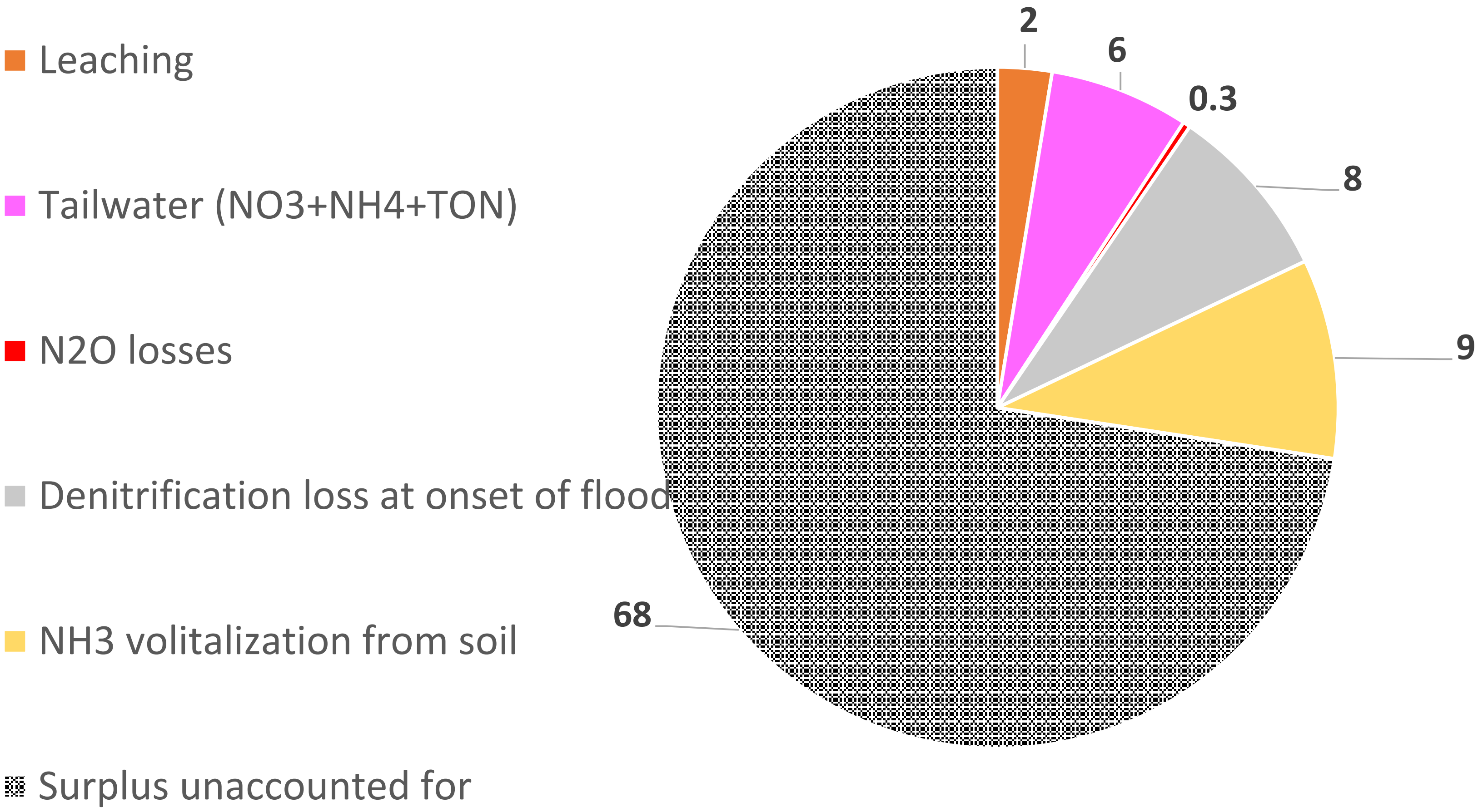
Liang et al., 2014

(Linquist et al., 2014; Krupa et al., 2011)

(Pittelkow et al., 2013; LaHue et al., 2016)

Based on preseason soil NO_3 levels before flooding (Linquist et al., 2006; Pittelkow et al., 2013,2014; Liang et al., 2014)

(Estimated from Huang et al., 2016)



Unaccounted surplus N (68 kg N/ha)

- Gaseous loss from plants
  - NH_3 loss from plant
- Denitrification
  - Mikkelsen (1987) estimated 25-35% loss via denitrification during growing season
    - 40-57 kg N/ha

End of season N losses from plants

- Losses can be high
- High losses associated with excess N rates
- NH_3 and amine losses from leaves?

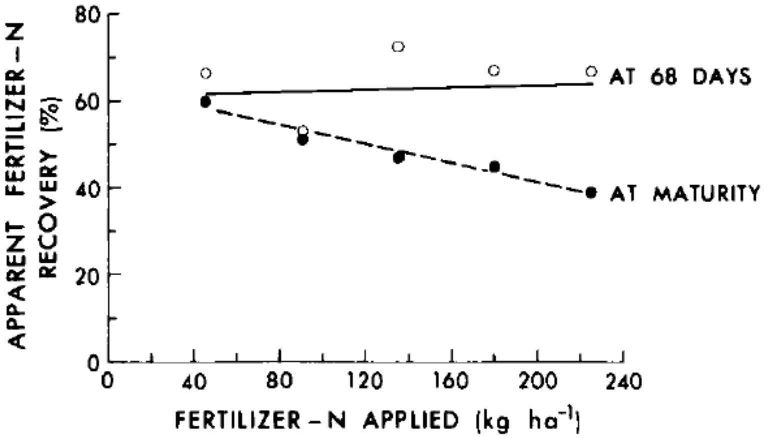
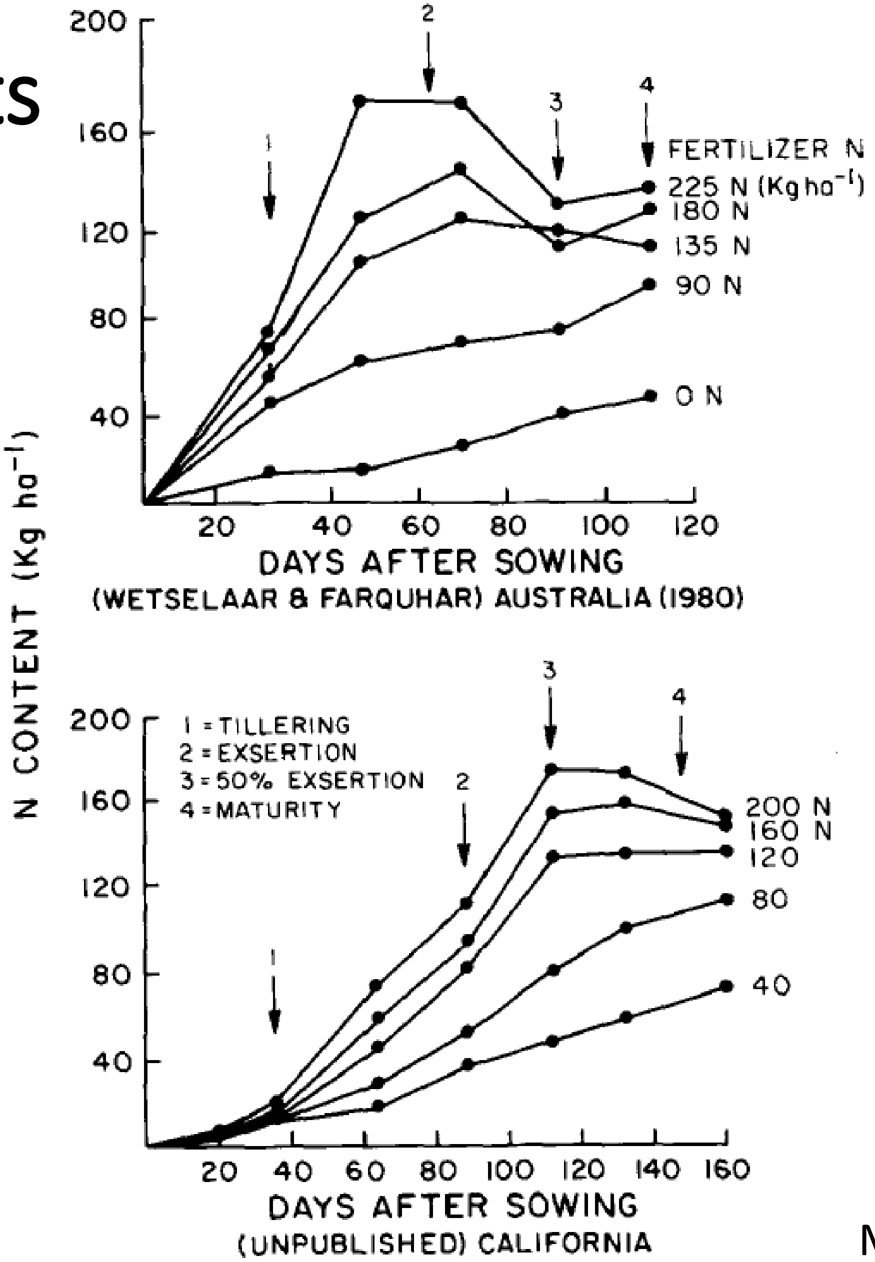


FIG. 7. Apparent fertilizer-N recoveries as affected by amount of nitrogen applied, calcul from Fig. 6, for 68 days after sowing and at maturity.

Wetselaar and Farquhar, 1980



Mikkelsen, 1987

Fig. 5. Losses of N from plant tops during the reproductive period of rice in Australia and California.

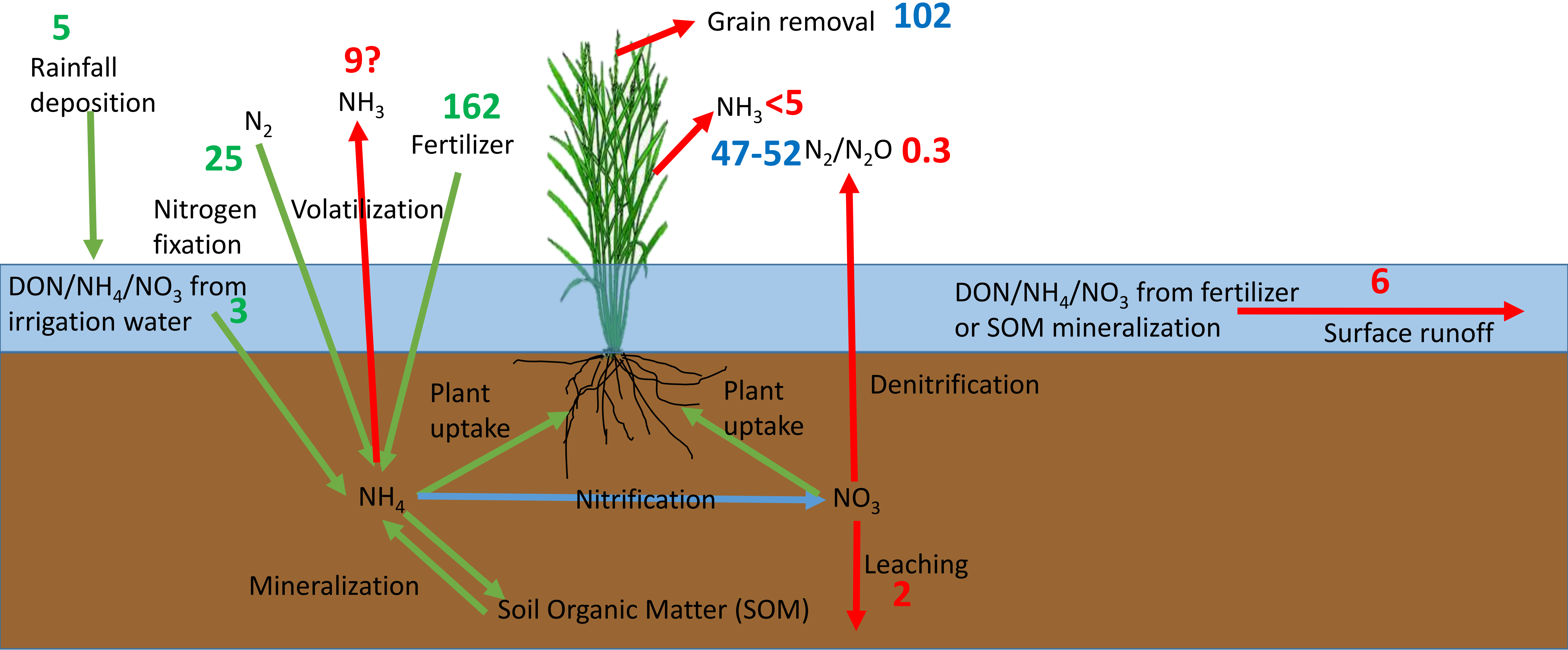
Annual reactive N losses (kg N/ha)

	Growing	Winter	Total
• Leaching	1.2	1.2	2.4
• Tailwater	1.9	4.2	6.1
• N_2O	0.19	0.14	0.33
• NH_3 from soil	8	0	8.0
• NH_3 from plant	<5	0	<5
• **TOTAL**	**11-16**	**5.5**	**16-21 kgN/ha**

Surplus N summary

• **Surplus N**	**68 kg N/ha**	
• Reactive N	16-21 kg N/ha	(8-11% of total N inputs)
• N_2 losses	47-52 kg N/ha	(24-27% of total N inputs: similar to Mikkelsen, 1987)

Nitrogen cycle in rice systems



Factors that will increase N loss

- Surface applied fertilizer
  - Increasing proportion of surface applied N
- Increasing N rates unnecessarily
  - Inefficient uptake and end of season losses
- Poor timing of drains
  - Promotes nitrification and denitrification losses
- Rainfall between fertilizer application and flooding up
  - delays flooding and causes nitrification of NH4 fertilizers.

Summary

- Total losses are 68 kg N/ha
- Most not to reactive N but to N_2 loss

- Reducing denitrification losses will improve NRE
- Efforts should focus on improving NRE while maintaining low reactive N losses

Thank you

Painting by
Dolores Mitchell