Approaches for improved food chain nitrogen use efficiency

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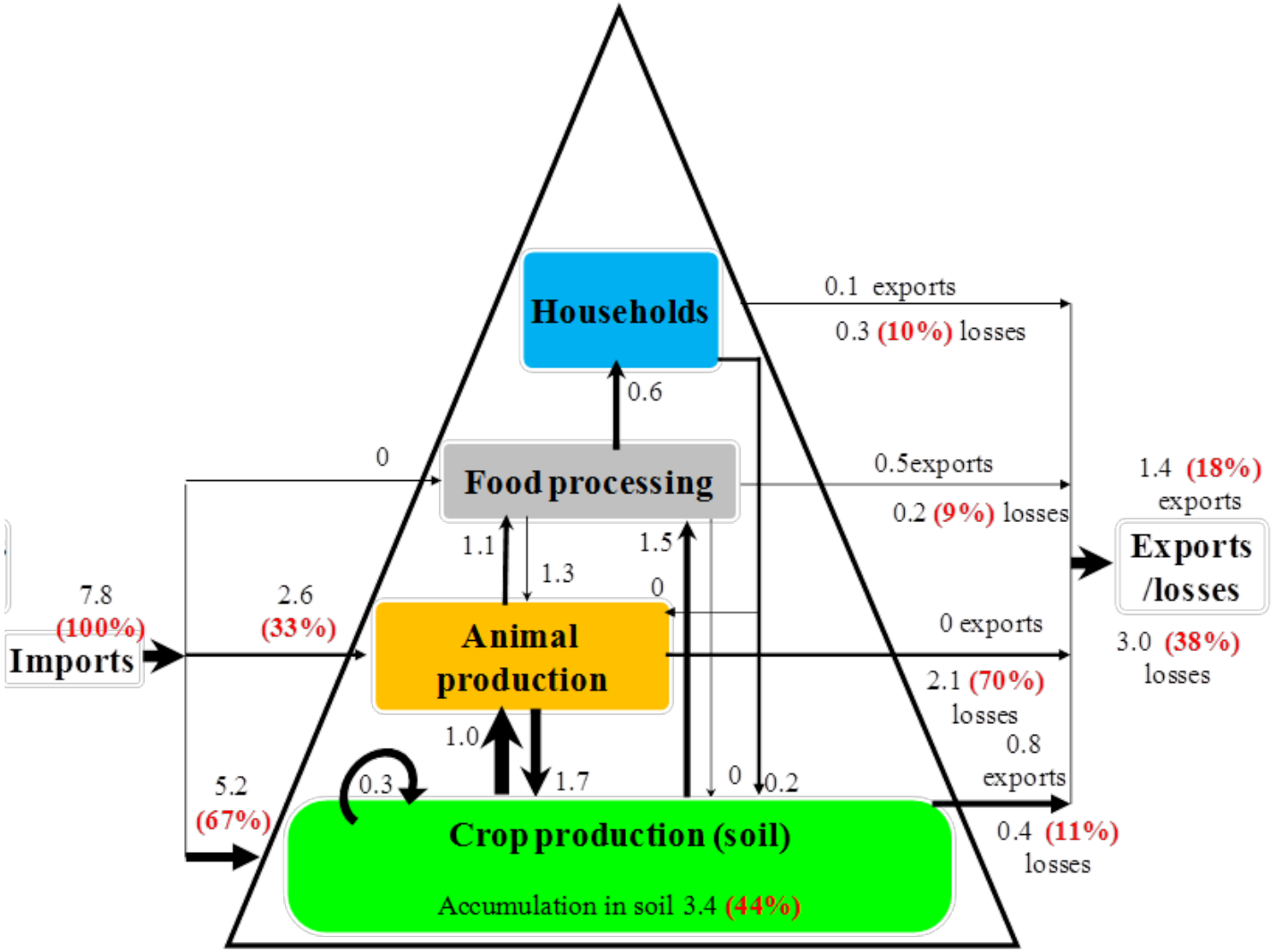
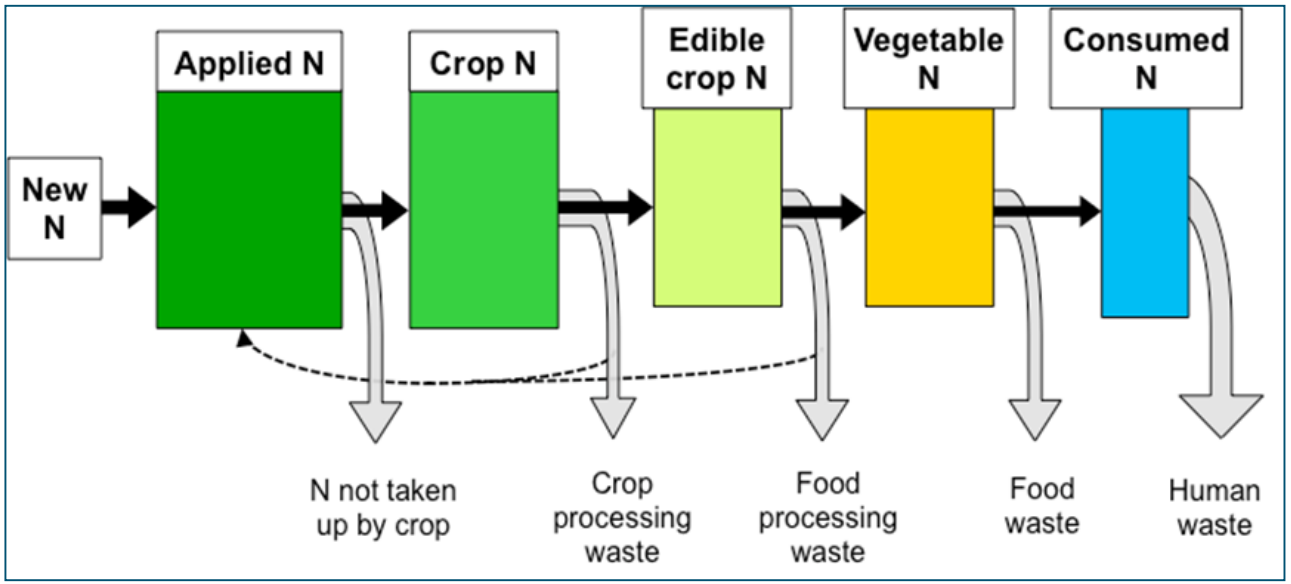
Food chain: from production to consumption and back



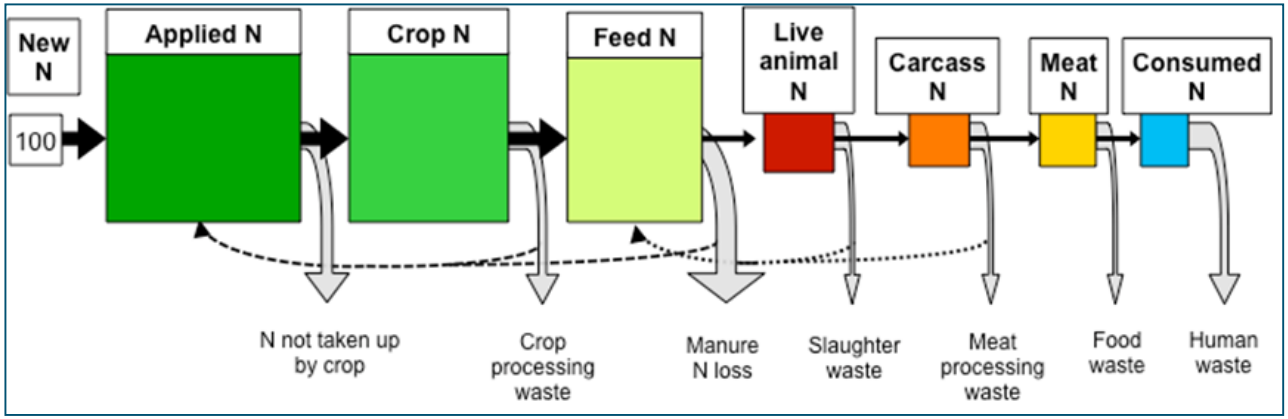
Ma et al., 2010, 2012

Nitrogen transfers in the food chain

Plant-source food



Animal-source food



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Leach et al. 2012

How is nitrogen use efficiency defined?

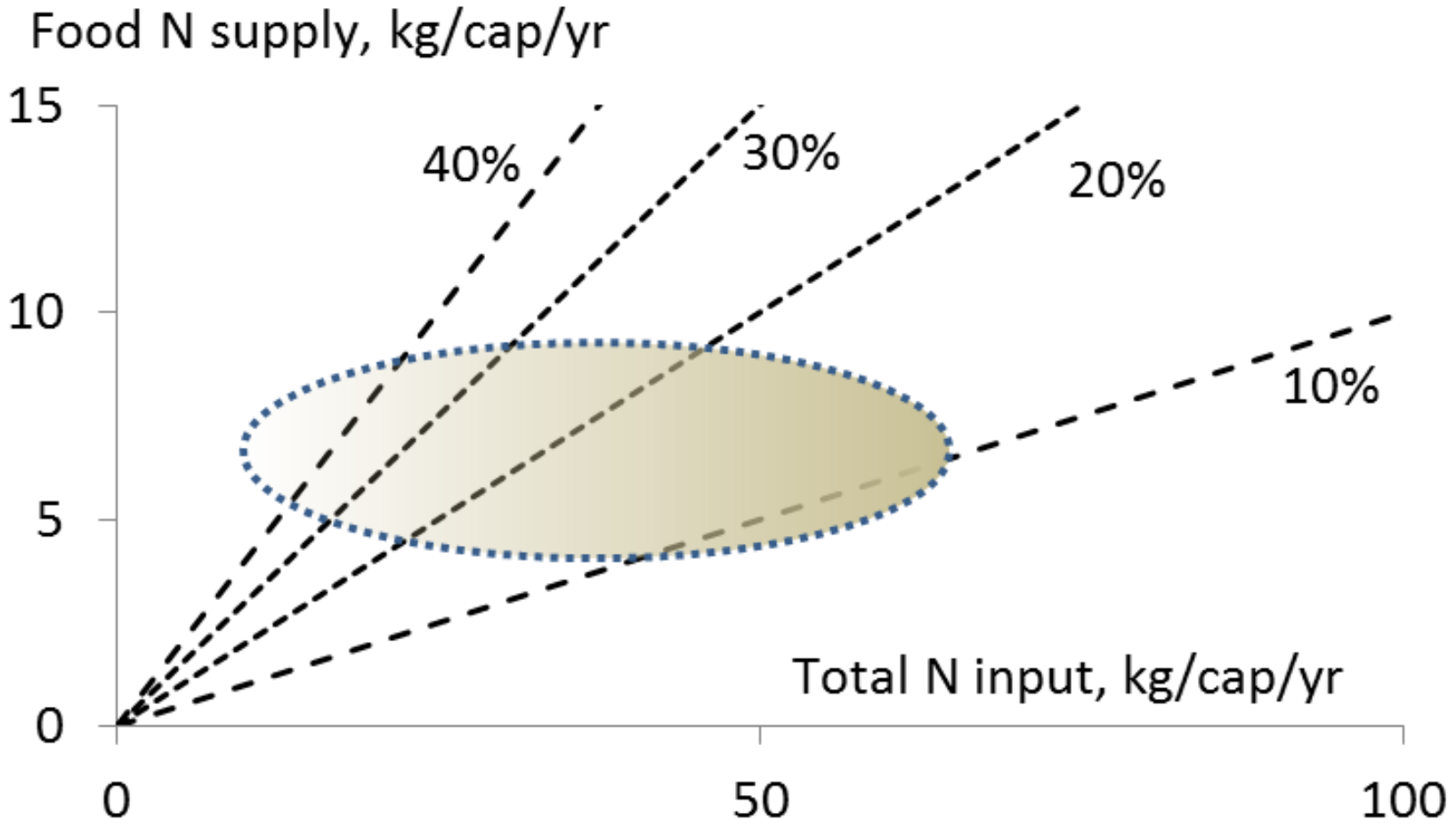
- Based on the mass balance of a system (compartment)
- NUE = N output / N input
- Can be applied to all systems

- Food chain NUE_{FC}:

$$NUE_{FC} = \frac{\text{Food N supplied to households}}{[\text{N fertilizer} + \text{BNF} + \text{atm. N dep} + (\text{import} - \text{export})]}$$

- Operational defined; no formal consensus yet

Wide variation in NUE_{FC} of EU-27 countries



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Based on: Erisman et al., 2017

Source of variations of NUE_{FC} at country level

- Variations in definitions of NUE_{FC}
- Uncertainties in the statistical databases (FAOSTAT)
- Import and export of food and feed
- Industrial uses of agricultural products

- Composition of the diet
- Waste collection and recycling
- NUE in animal production
- NUE in crop production

Exploring critical factors of NUE_{FC}

- Composition of the diet
- NUE crop production
- NUE animal production
- NUE food processing
- NUE retail
- Food wasting and losses in households
- Recycling of food losses and wastes
- Recycling of animal and human manure

Attainable NUE in crop and animal production

Product type	Attainable efficiency
Beef cattle (+ horses and small ruminants)	0.26
Byproducts: honey, wool	1.00
Crops	0.90
Milk (all species)	0.39
Eggs	0.48
Pig	0.49
Poultry (+ rabbit)	0.59

Godinot et al., 2015

Attainable N utilization efficiency of wastes, %

Waste	Collection efficiency	Gaseous losses*)	Utilization N effectiveness**)	NUE-wastes
Sewage	0-90	5-50	50-90	20-50
Kitchen	0-90	5-50	20-100	20-50
Retail	80-95	5-50	50-100	20-50
Food processing	80-95	5-50	50-100	20-50
Animal manure	30-100	5-50	30-80	20-50

*) during storage, composting and treatment
**) in animal production or crop production

Source: authors estimations

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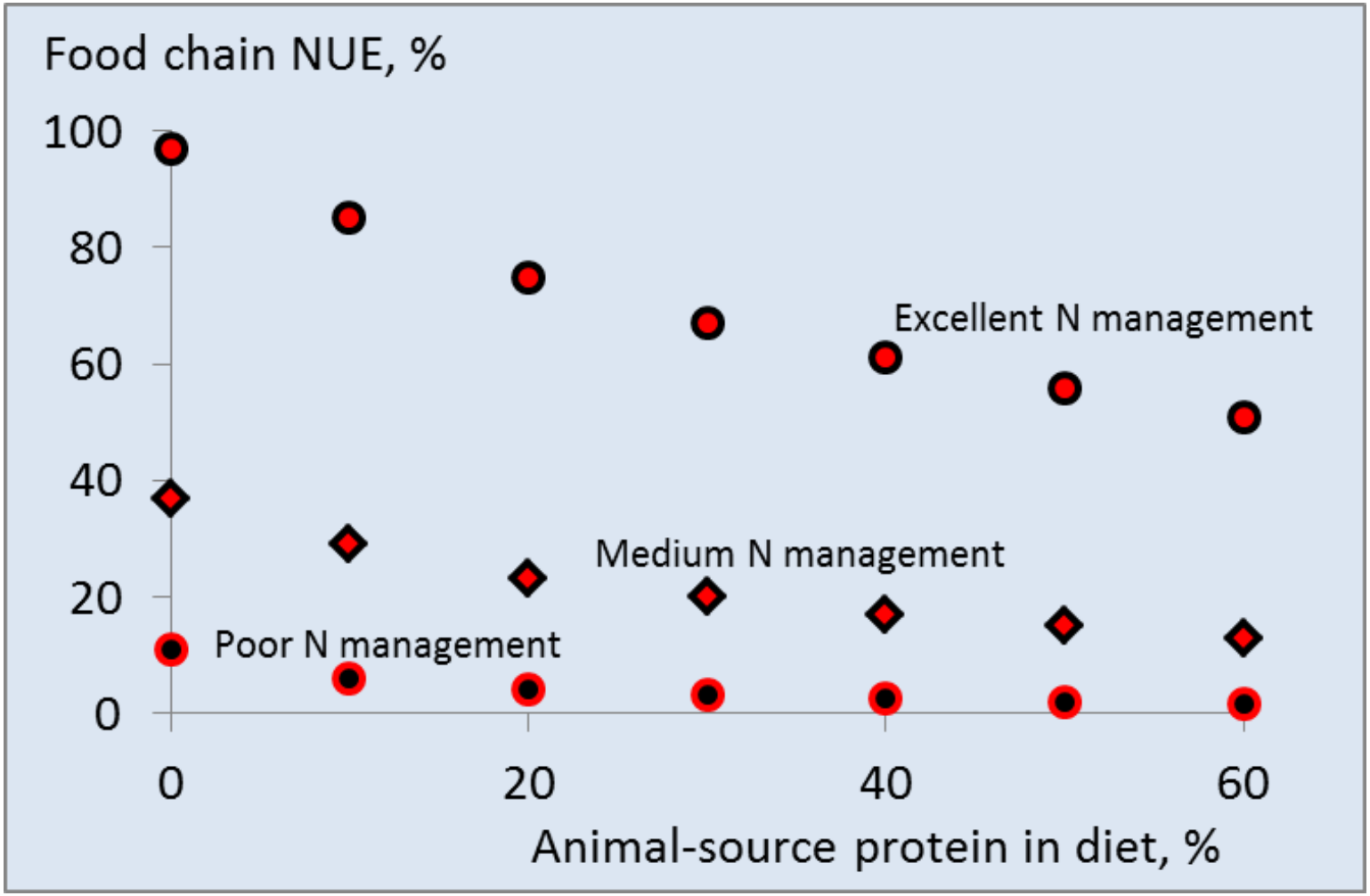
Attainable N use efficiency, fraction

Management variable	Management		
	poor	medium	excellent
NUE-crop production	0.4	0.6	0.8
NUE-animal production	0.1	0.25	0.4
NUE-food processing	0.6	0.8	0.9
NUE-Retail	0.7	0.8	0.9
NUE-Household	0.6	0.8	0.9
NUE-sewage waste recycling	0.2	0.3	0.5
NUE-household waste recycling	0.2	0.3	0.5
NUE-Retail waste recycling	0.2	0.3	0.5
NUE-food processing waste recycling	0.2	0.3	0.5
NUE-manure recyling	0.2	0.3	0.5

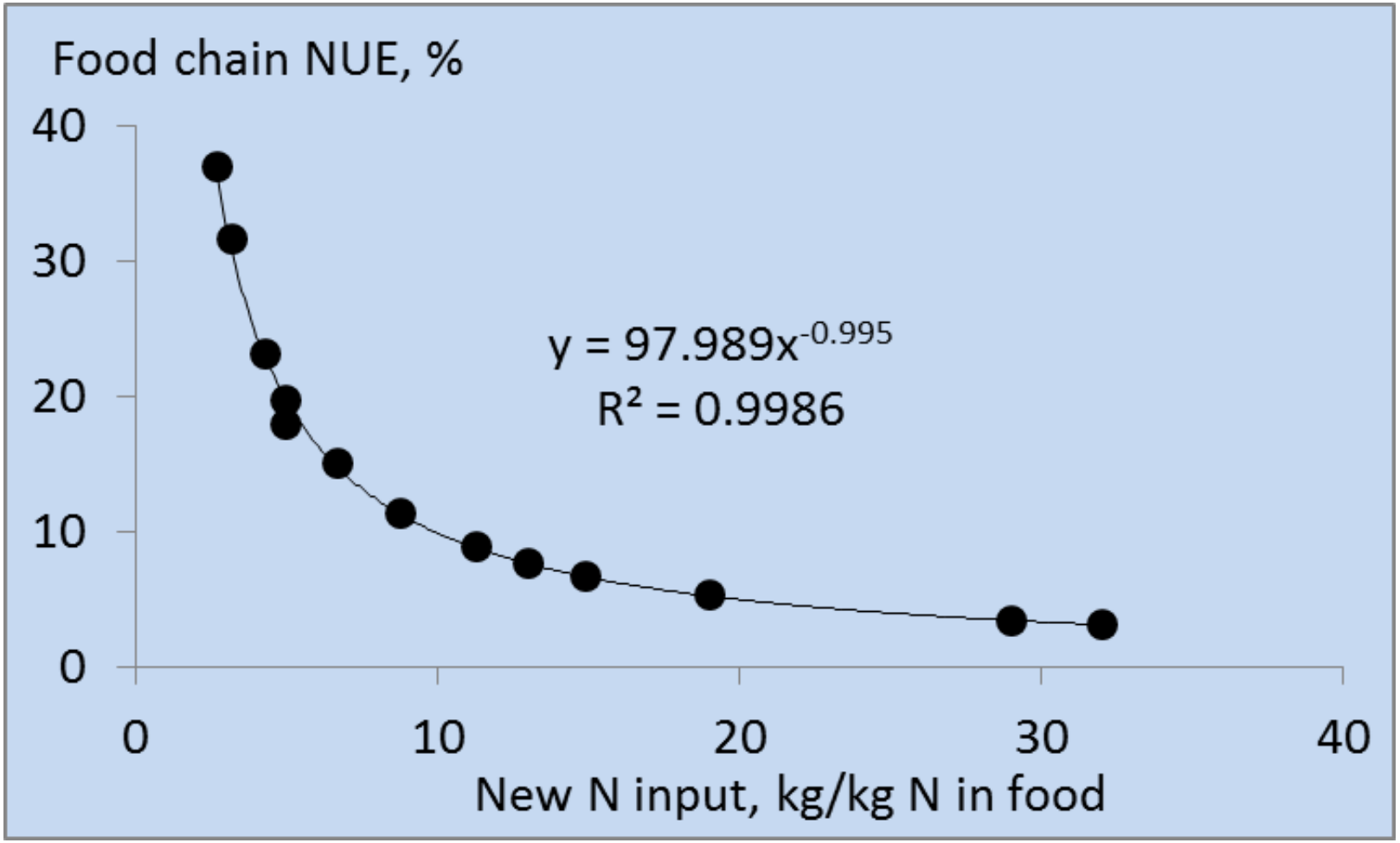
Source: authors estimations

Critical factors of NUE_{FC}: diet & management



Source: authors calculations

Relationship new N input vs NUE_{FC} *)



*) Assumption: 30% animal-source protein in diet

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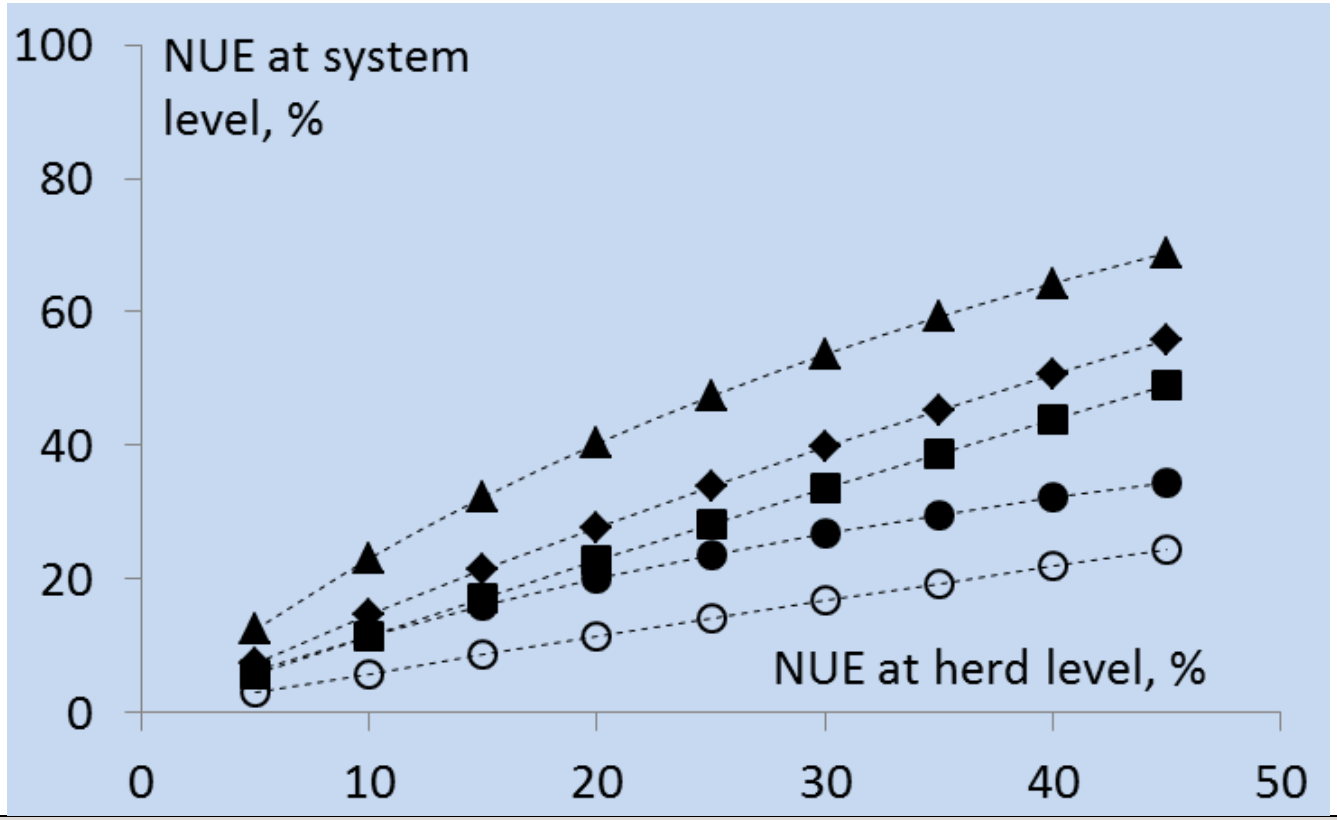
Source: authors calculations

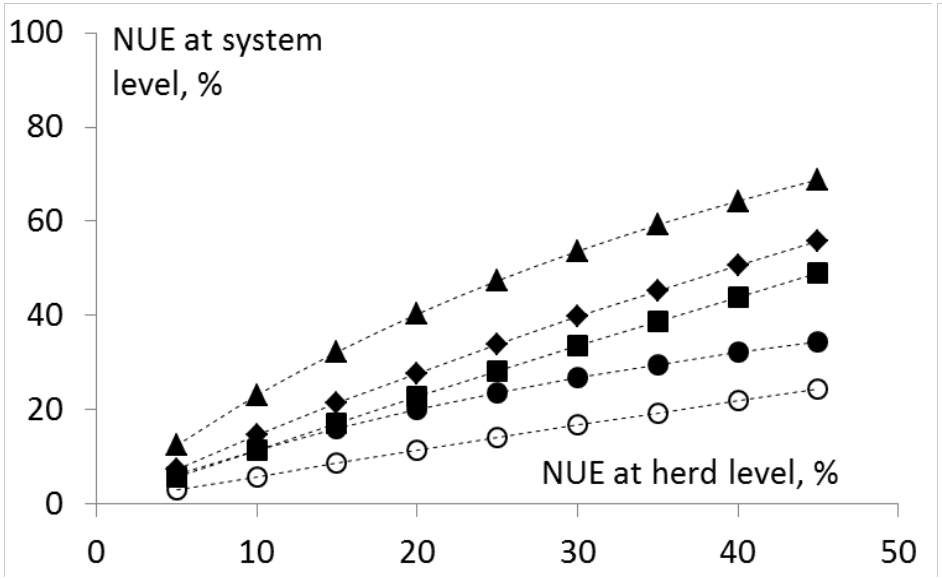
Exploring NUE_{herd} vs NUE_{system} relationships in animal production

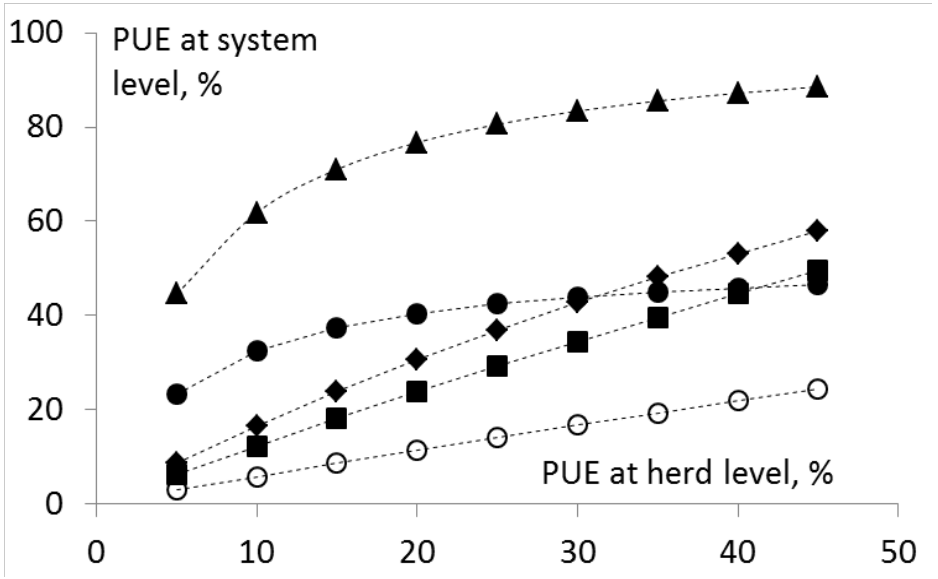


Open circles:	manure N loss 50%;	manure N recovery 30% ;	'new' N input recovery 50%
Filled circles:	manure N loss 10%;	manure N recovery 70% ;	'new' N input recovery 50%
Squares:	manure N loss 50%;	manure N recovery 30% ;	'new' N input recovery 100%
Diamonds:	manure N loss 50%;	manure N recovery 70% ;	'new' N input recovery 100%
Triangles:	manure N loss 10%;	manure N recovery 70% ;	'new' N input recovery 100%

Liu et al., 2017

Comparison of NEU and PUE in animal production





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Squares:	manure P loss 50%;	manure P recovery 50% ;	'new' P input recovery 95%
Diamonds:	manure P loss 50%;	manure P recovery 95% ;	'new' P input recovery 95%
Triangles:	manure P loss 1%;	manure P recovery 95% ;	'new' P input recovery 95%

Liu et al., 2017

Main implications

- NUE_{FC} increases more than proportional when the need for new N input per unit N in food decreases
- NUE_{FC} is low when NUE of crop and animal production is low
- Relative large effects of:
  - Reducing food wastes
  - Increasing recycling efficiency when losses are large

Main approaches to increase NUE_{FC}

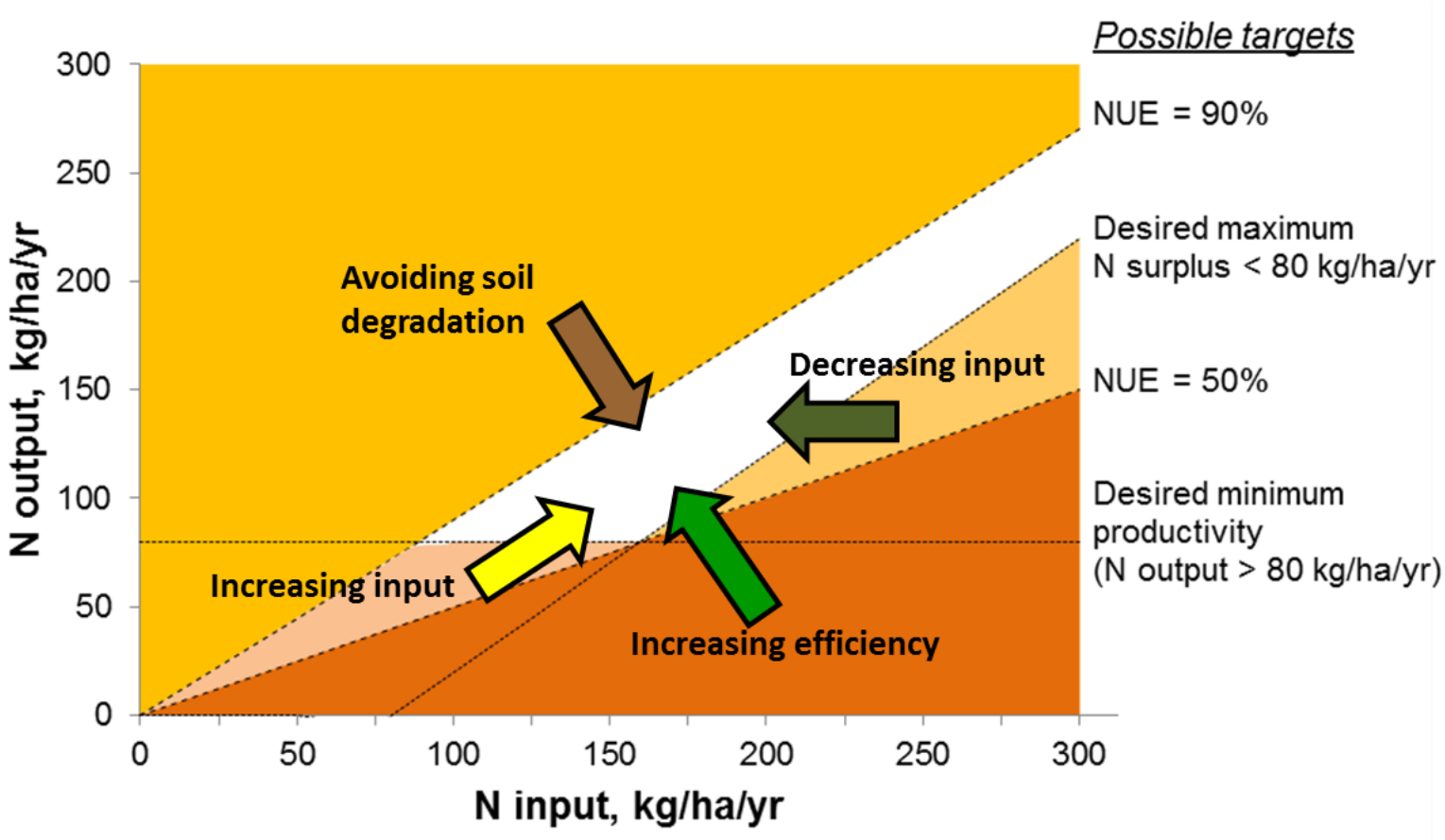
- Reduce the proportion of animal-source protein in diet
- Reduce food losses
- Increase NUE in crop production
- Increase NUE in animal production
- Reduce N losses from animal manures and wastes
- Improve the recycling/utilization of N from wastes

Development of target values (1)

Interpretation	Nitrogen Use Efficiency (NUE) (%)		
	Cropping systems	Mixed crop-livestock systems, 1 LSU/ha	Mixed crop-livestock systems, 2 LSU/ha
Soil N mining	>100	>80	>60
Risk of soil N mining	90-100	60-80	50-60
Balanced N fertilization	70-90	40-60	30-50
Risk of N losses	50-70	30-40	20-30
High risk of N losses	<50	<30	<20

EU Nitrogen Expert Panel, 2015

Directions of change



EU Nitrogen Expert Panel, 2015

Development of target values (2)

Interpretation	Food chain nitrogen use efficiency (NUE, %)			
	Animal-source protein in diet, %			
	< 10	10-30	30-50	>50
Low	<20	<15	<10	<10
Medium	20-80	15-70	10-60	10-50
High	>80	>70	>60	>50

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Demand-side measures to increase NUE_{FC}

- Soft measures:
  - Education / awareness raising (e.g., N footprint)
  - Health promotion initiatives
  - Product labeling

- Hard measures
  - Price differentiation during product life-time
  - Consumption taxes
  - Consumption subsidies

Supply-side measures

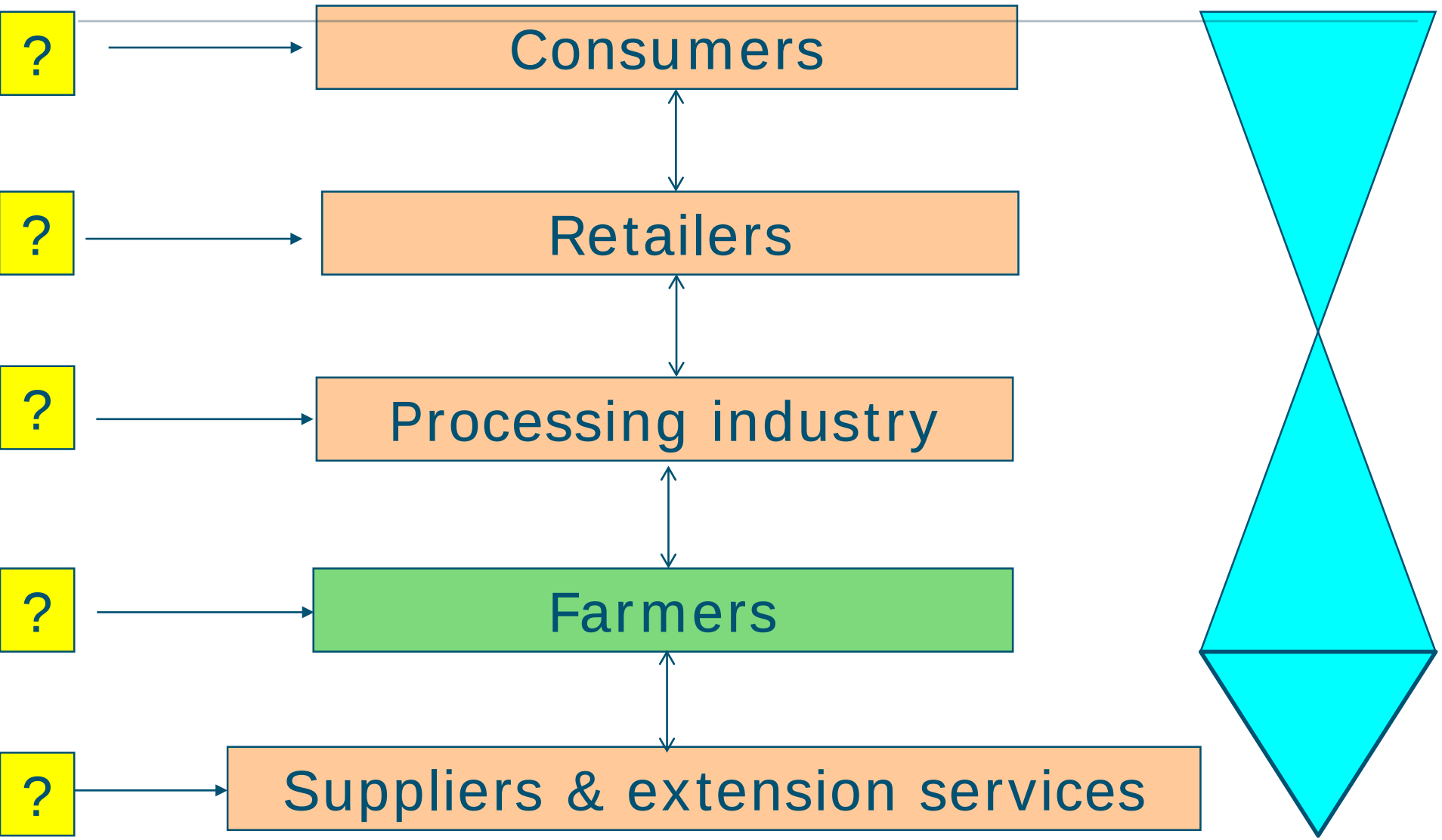
- Soft measures:
  - Good agricultural practices
  - Extension services
  - Development of new technologies

- Hard measures
  - Regulations (e.g. Nitrates Directive, WFD, NECD, ….
  - Subsidies and taxes
  - Mixtures (e.g. Cross Compliance)

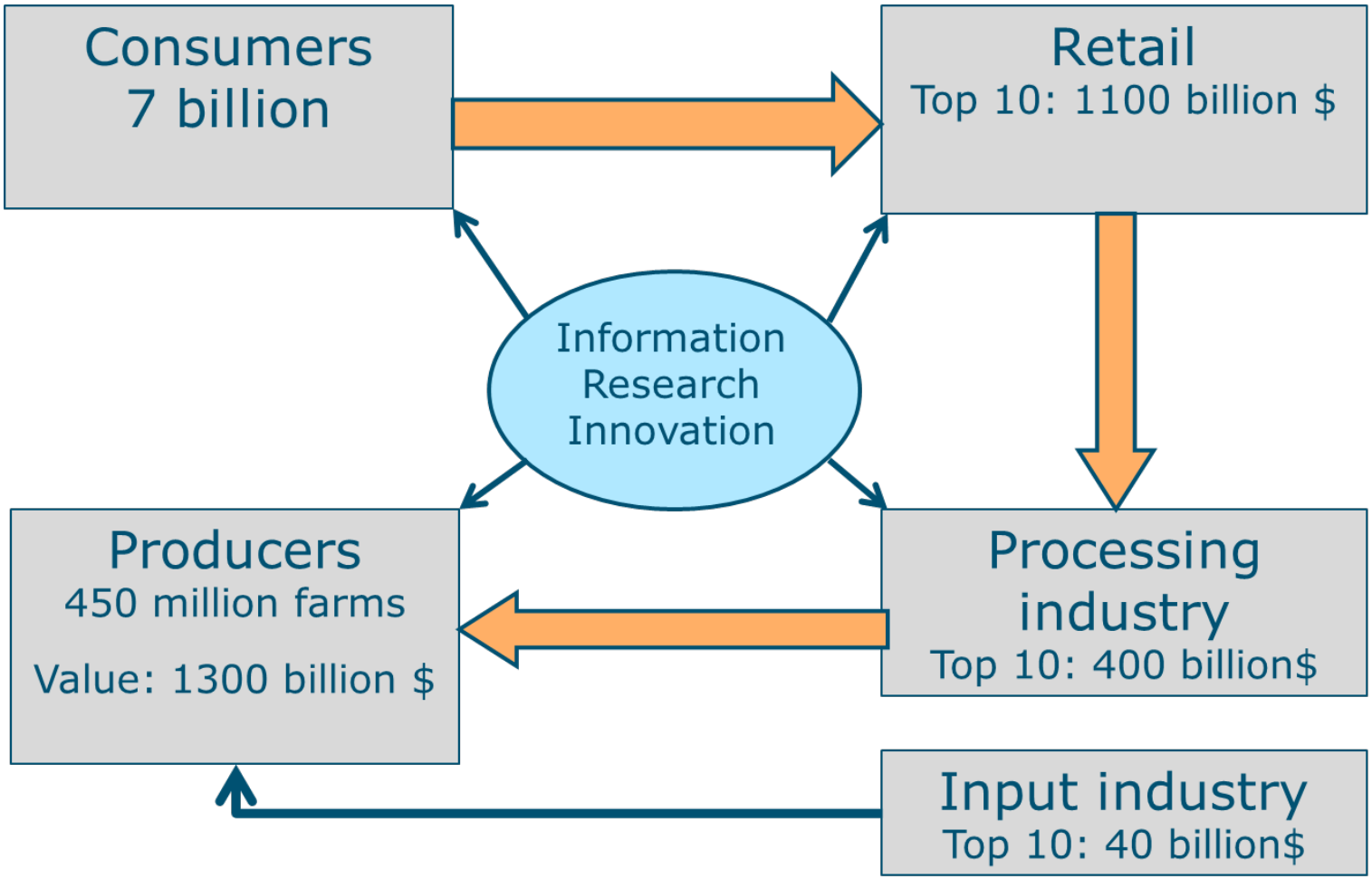
Are current measures effective / sufficient?

- Estimated NUE_{FC} at country level is increasing in EU-27 countries between 1980-2010, (from ~15 to ~25%; Erisman et al., 2017), mainly due to increases of
  - Manure N utilization
  - NUE in animal production
  - NUE in crop production
- Relative NUE in crop+animal production at country level in EU-27 is 43% (range 28-78) (Godinot et al., 2016)
- Level of implementation / enforcement of measures differs between countries

Who is the addressee of the measures?

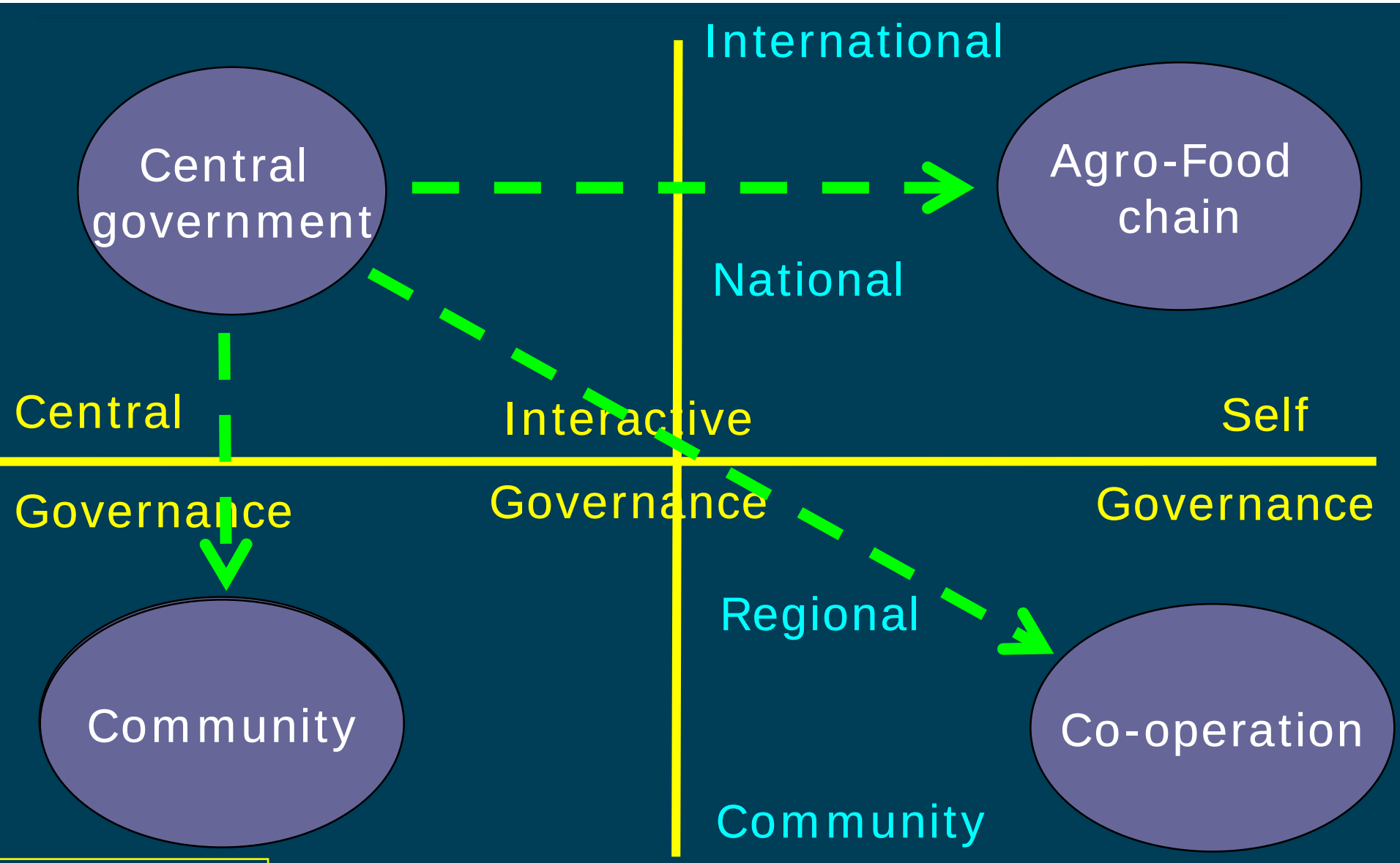


Main actors in the global food chain



Source: von Braun (2008).

From government to governance.....



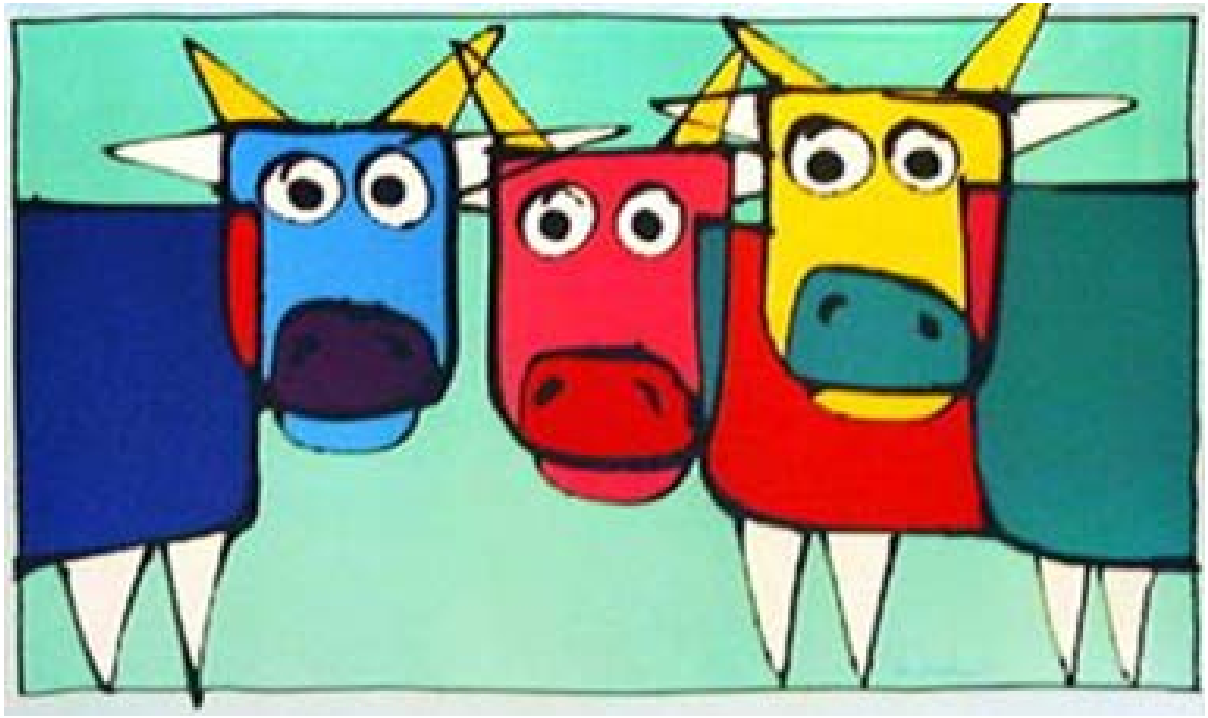
Next steps

- More studies on NUE in food chain needed
- Scrutiny of NUE_{FC} methodologies needed
- More cooperation needed between farmers, scientists, private sectors, governments
- More effective governance related to:
  - Implementation of BMPs, BATs, target values
  - Demand-side measures
  - Cross compliance

Conclusions / propositions

- Food chain analyses of NUE_{FC} are interesting but need further development and testing
- Analyses of NUE_{FC} are related to N footprint analyses
- Composition of the diet, NUE in crop and animal production, and recycling efficiency of wastes are main factors of NUE_{FC}
- There are many effective measures, but the combination of these and the implementation/enforcement can be improved
- New governance approaches should be explored further

Questions?



Changes in research

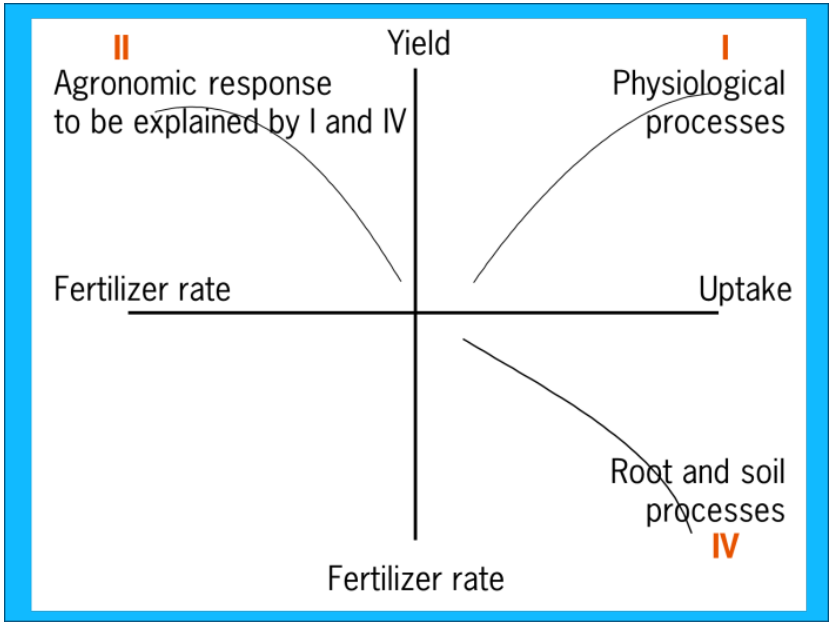
- Increasingly internationalised
- Increasingly privatized
- Increasingly short-term
- Decreasing in volume

➢ Changes the relationships between science, industry and governments

➢ Do farmers, citizens and politicians trust research results sufficiently?

How is nitrogen use efficiency defined?

- **RE** = apparent recovery efficiency of applied N
- **PE** = Physiological efficiency of applied N
- **IE** = Internal utilization efficiency of N
- **AE** = Agronomic efficiency of applied N
- **PFP** = Partial factor productivity of applied N



Dobermann, 2008