Evaluation of nutrient (nitrogen) efficiency- the concept of primary nutrients

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Content

Implications

- Different nutrient flows are not commensurate (eg.art. fertilizer, FYM, fodder can’t be counted together such as they are)
- There can be on-farm and off-farm processes in any target system; both must be included into evaluation
- Any recycling nutrient (=secondary nutrient, M) is due to use of primary nutrient (P); any use of primary or secondary nutrient results yield (Y)
- The indicator of nutrient efficiency is the amount of yield per unit of primary nutrient (Y/P). This ratio can be improved by improving field efficiency and improving recycling
- The concept of primary nutrients can be used to evaluate any kind of primary production systems

Background and objectives

Evaluation of nutrient efficiency

Traditional evaluation methods are based on input – output ratios (ratio or difference)

- NUE (nutrient use efficiency):
  yield per unit input (ratio)

- Surface balance:
  input nutrients into field minus yield (difference)
  yield per input nutrients into field (ratio)

- Farm gate balance:
  nutrients into farm minus products from farm (difference)
  products from farm per nutrients into farm (ratio)

Validity of evaluation methods?

- None of the evaluation method mentioned doesn't make any difference between primary or secondary nutrients (virgin or recycling)

- Farm gate balance doesn't make any difference between primary products (crop) and secondary products (animal)

Evaluation methods threat any kind of nutrients as commensurate – even different flows of nutrients are not commensurate!

Present evaluation methods are not valid, or interpretation of evaluation is misleading

How to describe nutrient utilization?
A= crop farm, B= pork farm, C= dairy & beef farm

	kg	kg	kg	kg		%	%	%	%	kg
Farm	External input	Internal input, FYM	Farm crop yield	Output to sell Crop	Anim	Field balance	Farm gate balance	Animal balance	NUE	Farm surplus
A	100	-	80	80	-	80	80	-	80	20
B	100	100-40 =60	100	-	40	62	40	40	62	60
C	100	120-20 =100	120	-	20	60	20	17	60	80

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Farm	External input	Internal input, FYM	Farm crop yield	Output to sell Crop	Anim	Field balance	Farm gate balance	Animal balance	Efficiency, primary balance	Farm surplus
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C	100	120-20 =100	120	-	20	60	20	17	120	80

Nutrient categories

- Primary nutrients (ie. virgin nutrients: art. fertilizers, biol. fixed nitrogen; nutrients from outside ”active biosphere”)
- Secondary nutrients (ie. recycling nutrients: FYM, seeds, sewage sludge, ash,…)
- Primary products (yield, ie. crop products/biomass)
- Secondary products (animal products; production based on primary products)
- Losses (water, soil, air)

Introduction to nutrient utilization
- crop production only, no internal recycling

A) No internal recycling (mainly theoretical in any soil-plant system; hydroponics is analogous practical example)

Example 1a:

80 % of fertilizer N is uptaked by biomass, harvest index is 60 %

=> 48 % of fertilizer N can be harvested

=> N efficiency is 48 %

Conclusion: In case of no mineralization, maximum N-efficiency equals harvest index; only high mineralization potential can provide high nutrient efficiency!

Introduction to nutrient utilization
- crop production only, internal recycling

B) Internal recycling (in reality all soil-plant systems)

Example 1b:

100 kg N is given as fertilizer, 80 kg N is harvested in yield

In long run part of nitrogen is accumulated into soil

=> in dynamic balance stage soil N-storage can provide N-yield equaling 80 % of N-input.

This is how nutrient efficiency (%) is defined:

output yield / input nutrients x 100 %

Introduction to nutrient utilization
- crop – animal production, external recycling

Example 2:

Fertilization 100 kg N, yield 80 kg N

⇒ Manure 40 kg N => yield(manure) 30 kg N

⇒ Output animal products 20 kg N

Evaluation by classic input – output methods

- Farm gate balance 20/100 = 20%
- Surface balance (80+30) / (100+40) < 80 % (~79%)
- NUE = surface balance

Classic interpretation:

⇒ Example1b is more efficient than example 2

Replacing classic evaluation methods by the concept of primary nutrients

- As comparision of examples 1a and 1b it can be noted, that increasing recirculation improves nutrient efficiency;

- However, as comparision of examples 1b and 2, increasing recirculation reduces nutrient efficiency

This is the misleading result of classic nutrient evaluation and indicates nonvalidity (invalidity) of evaluation method;

the concept of primary nutrients provides an alternative to evaluate nutrient efficiency.

Key results and discussion

The concept of primary nutrients

Primary nutrient efficiency, P(eff)

$$= Y/P \qquad (I)$$
$$= C \times U \qquad (II)$$

Y = yield

P = primary nutrient input in crop production

C = circulation factor, (P+M)/P

M = secondary nutrient input in crop production

U = utilization rate (”surface balance”), Y/(P+M)

$$C \times U = (P+M)/P \times Y/(P+M) = Y/P$$

All of the nutrient flows must be able to describe by these (P, M, Y) dimensions!

On-farm and off-farm processes (on-site, off-site)

Modern agriculture is more like networking process with other actors rather than independent, self-sufficient process on single farm.

⇒ Various processes occur outside the farm (off-farm), even the final process occurs as on-farm process; for instance animal production (on-farm) on the farm is based on purchased fodder (off-farm) production.

On-farm and off-farm processes must be included into evaluation of nutrient efficiency, otherwise the result is distorted.

Potential off-farm processes

1) Crop production of purchased fodder and seeds

2) Production of purchased manure
(crop and animal production)

3) Crop production by sold manure

[4) Crop production by sold products (sewage sludge)]

[5) Production of purchased animals (crop and animal production)]

Off-farm processes and ”shadow farms”

It is possible that several off-farm processes are connected into one single target farm simultaneously. Off-farm processes can be independent or dependent - but the information about it is missing (most often).

From methodological point of view it is necessary to standardize (fix) all of the off-farm processes (unless off-farm processes are including to our target system).

To keep it simple and easy to understand and illustrate, all of the off-farm prosecces are defined to be independent.

Furthermore, each of the off-farm process takes place on specific farm (”shadow farm”).

Fixed off-farm processes

1) Purchased fodder/seed is produced:

1 kg primary nitrogen equals 2/3 kg nitrogen in yield (67% N-efficiency)

2) Purchased FYM is produced:

1 kg primary N = 2/3 kg N in yield = 1/3 kg N in sold FYM (50% of N in fodder ends up in FYM).

3) Crop production by sold manure:

1 kg N in sold manure equals 1/5 kg N in yield (20% N-efficiency)

Figures are based on averages in Finnish agriculture.

Evaluation of target system

Total target system (S) is aggregated from all of the sub systems:

S = F(target) + F(shadow 1) + F(shadow 2) + F(shadow 3) +…

In case the focus is on one specific farm, fixed values of shadow farms must be used (even in case that the actual information about shadow farms is available).

In case the focus is on the integrated production system (there is interaction between target farm and shadow farms) actual information should be used in the first place and fixed values only in case of missing data.

Specification of nutrient flows and yields

FARM	Primary N (P)	Second. N (M)	Yield (Y)
F(target)	P(fertilizers)	M(own manure)	Y(own fodder)
	P(biol. N-fix)	M(sold manure)	Y(cash crop)
		M(own seed)	Y(own seed)
F(shad1)	P(fert. for seed)	M(purch. seed)	Y(purch. seed)
	P(fert. for fodder)		Y(purch. fodder)
F(shad2)	P(fert, for fodder)	M(purch. manure)	Y(purch. manure)
F(shad3)			Y(sold manure)

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Thank you!

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