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Nutrient Performance Indicators:
The importance of farm scale assessments, linked to soil fertility, productivity, environmental impact and the adoption of grower best management practices.

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Summary

- Efficient and effective use of plant nutrients is essential to meet global Sustainable Development Goals.
- To estimate broad scale nutrient use efficiency, partial nutrient balance (PNB) and partial factor productivity (PFP) indicators can be derived at a range of spatial and temporal scales and provide some intelligence on nutrient use.
- Partial factor productivity answers the question "How productive is this cropping system in comparison to its nutrient input?" It will, by definition, decline with increased nutrient inputs.
- Partial nutrient balance answers the question "How much nutrient is being taken out of the system relative to the amount supplied?" System PNB only indicates the fate of nutrients removed in harvested produce. It does not consider other transfer processes and so is not an indicator of nutrient loss to the environment.
- These indicators require good quality scalable (i.e., regional or local) data, clarification of the assumptions used and identification of the boundaries of the system assessed.
- The use of national or global indicators may mask important spatial variations among regions, farming systems, and farms, the level at which interventions will be applied. Farm level nutrient performance data are needed to develop appropriate interventions to improve nutrient performance.
- Trends over time in regional, catchment or farm scale indicators to gauge trends are preferable to once only broad scale assessments.
- Even though it presents challenges, mixed crop and livestock systems as well as cropping systems should be considered in the assessment of nutrient performance indicators.
- A single performance indicator is likely to be misleading in the assessment of the efficiency and effectiveness of nutrient management. To provide meaning, it is proposed that other essential indicators be included and they would consider:
  - Changes in soil nutrient levels or soil fertility.
  - An assessment of the magnitude of the nutrient-limited gap between actual and achievable yield.
  - Evidence of the adoption of nutrient best management practices such as the adoption of soil testing, farmer training, and/or farm record keeping, etc.

Purpose

This paper seeks to provide feedback on how the impact of plant nutrients can be assessed for a sustainable future. Specifically, it discusses the strengths and limitations of using indicators of nutrient use efficiency as indicators of nutrient performance.

Context and Background

The use of fertilizers is fundamental to feeding the global population, with around half of current food production made possible by balanced crop nutrient input. At the same time, there are parts of the world where fertilizers are under-used so that food security is threatened, or where they are overused to the point of contributing to environmental pollution. In order to bring balance to these two situations, it is useful to distinguish between effectiveness and efficiency of nutrient use. Efficient (e.g., increasing output per unit of fertilizer applied) and effective (e.g., increasing farmer profitability) nutrient use will balance environmental, economic and social issues, as the improvements in all three are not mutually exclusive.

There has been discussion leading to the post-2015 sustainable development goals about how the success of nutrient management strategies can be assessed. Achieving improved efficiency and effectiveness in fertilizer use will largely be in the hands of the users, who are the farmers of the world. This summary seeks to provide feedback on how the impact of plant nutrients can be assessed for a sustainable future.

The complete assessment of nutrient performance encompasses a wide range of social, economic and environmental indicators, and IPNI (International Plant Nutrition Institute) has worked closely with stakeholders to develop a range of nutrient performance indicators that reflect the diversity of impacts that come from nutrient best management practice. A summary of these is given in the **Appendix Table** and these are mapped against the indicators in the Sustainable Development Solutions Network (SDSN) report "Indicators for Sustainable Development Goals" (2014). These farm level indicators are highly interactive, similar to the interactions noted for the SDSN indicators, which reflects the opportunity to scale some SDSN indicators to the farm or regional scale.

The "Planetary Boundaries" described by Rockström et al. (2009) has strongly influenced some of these indicators within the earlier versions of the SDSN report (2014). The concept has been challenged (e.g., Lewis, 2012; Nordhouse et al., 2012), as well as the suggested numerical limit for N (de Vries et al., 2013) and P (Carpenter and Bennett, 2011). Some of the criticism of the concept concerns the un-even distribution of fertilizer use and lack of connectedness (other than for nitrous oxide, which becomes mixed through the global atmosphere), which indicates that targets set at regional, or farm scale are more appropriate. Setting these goals collaboratively with farmers is probably the most appropriate scale as this is where the improvement in both crop productivity and environmental footprint will be derived. It is at the farm or regional level where interventions are most likely to show benefits, so targets or benchmarks for farms or farmers, and education and training on how to meet those targets are appropriate. So, the primary system boundary should be the farm, and aggregation from the farm to regional and national levels should be the basis for driving improvement.

Nutrient performance indicators

Selecting the most appropriate performance measure requires a detailed understanding of the processes involved in acquisition, residence time, allocation, remobilization and losses within plants. The acquisition or uptake efficiency and then remobilization or utilization efficiencies are important to plant breeders as they look for traits that can be used in selecting more efficient genotypes. Responses can be expressed as agronomic efficiencies or apparent recovery efficiencies, but both require a nil fertilizer application treatment to estimate the extra yield in response to added nutrient. Of a wide range of potential methods to assess nutrient use efficiency, partial nutrient balance (PNB; nutrient removal to use ratio) and partial factor productivity (PFP; crop yield per unit of nutrient applied) offer the benefits of being readily assessed for fields, farms, regions or nations, and together they link productivity and nutrient cycling at these scales.

PNB is only one of a range of nutrient performance indicators, and **Table 1** shows a selection of these. These indicators show that the use of plant nutrients does not have a single dimension, but sound nutrient management is based on balancing economic, social and environmental goals. Any single indicator may be prone to misinterpretation and may fail to bring attention to unintended compromises in overlooked dimensions (Fixen et al., 2014).

For example, a low removal-to-use ratio may be appropriate if the soil requires building up of N, P or K status. In that case, the extra nutrient enters soil pools (including soil organic matter N and P fractions) that will reduce the external input demand for those nutrients in the future, and in this situation they are not lost to the environment. However, if soil loss processes such as leaching, denitrification and erosion are high, and the extra nutrient can be transferred from one place to another—possible adverse environmental effects may result.

Alternatively a high nutrient removal-to-use ratio (PNB) may occur if the crop has access to large pools of available nutrients in the soil, so that residual fertility is being drawn upon. If soil fertility is low, then a high value will result in soil degradation and reduce fertility down to and below critical concentrations necessary to maintain soil fertility, soil health, and productivity.

Table 1. Dimensions of nutrient use efficiency in cereals using N as an example (after Dobermann, 2007).

Term	Calculation	Range for N in cereal cops harvested for grain.
Cumulative Expressions		
Partial Nutrient Balance (Nutrient Removal Ratio)	PNB = kg nutrient removed/kg applied = Ug/F (kg/kg)	0.1 to 0.9 kg/kg; >0.5 where background supply is high and/or where nutrient losses are low; >1 implies soil fertility mining or potential productivity degradation
Partial Factor Productivity	PFP = kg yield/kg nutrient applied = Y/F (kg/kg)	40-80 kg/kg: >60 in well managed systems, at low N use or at low soil N supply
Nutrient Balance Intensity	NBI = kg nutrient removed/ha less kg nutrient applied/ha. = (Ug-F) (kg/ha) *OR* = kg nutrient removed/unit of yield = (Ug-F)/Y	The closer the difference is to zero, the smaller the amount of nutrient accumulated in the system. Positive values could reflect a decline in the soil fertility.
Relative Expressions		
Agronomic Efficiency	AE = kg yield increase/kg nutrient applied = $(Y-Y_0)/F$	10 to 30 kg/kg; >25 in well managed systems, at low N use or at low soil N supply
Y=crop yield with applied nutrients; Y_0=crop yield with no applied nutrients; F=fertilizer applied; Ug= crop nutrient uptake into harvested portion.		

Other nutrient performance indicators can be developed, based on the apparent nutrient balance rescaled to an area (e.g., per hectare) or a productivity (e.g., per tonne of grain) basis. This type of index helps in comparing systems with large productivity differences, but does not give context for the impact of the nutrient surplus or deficit. Small surpluses over large production systems may have quite different impacts to large surpluses in small or isolated systems.

The selection of appropriate performance indicators depends on a range of issues concerning how the defining data are collected and their intended use. Some of these factors are:

- **The boundaries of the system.** In food production systems, the boundary could be from manufacture or mining, through the production system, then into food processing, distribution, and consumption and then to waste and waste processing. Even though nutrients ultimately cycle within the global system, farm, regional or catchment cycles may not be connected. So the system boundary to understand nutrient cycling for many agricultural studies is within the farm boundary rather than a field, mainly because fields are used for different crops grown in an integrated system rather than in isolation. The spatial scale used to reference the efficiency—field, catchment, country or continent—can also change the nature of the metric derived.
- **The time scale.** Within production systems, recognition of the cycle of operations is important, and because fields are usually not cropped all the time, the length of the time between application and removal will be a function of the crop types. In low intensity systems this may be a number of years, while in more intense production systems it may be a year or even less. Given inter-annual variations due to climate, a smoothed time series of these indicators would best serve to assess trends, and this would be much more representative than a single annual value.
- **The numerator in the nutrient performance expression.** The numerator in any of the expressions in **Table 1** are outputs from the system, such as the mass of grain, aboveground biomass or total growth, or the nutrient contained therein, depending on the system of interest.
  - While good quality, publicly available production data are routinely collected at a range of scales, large regional and temporal differences in N and P content of outputs such as grain should be recognized and regional rather than national or international values should be used (Jensen and Norton, 2012).
  - Comparisons of PFP only make sense within a single crop. To compare across crops or farming systems with mixed livestock and grain, the numerator of PNB is preferred.
- **The denominator in the nutrient performance expression.** The denominator should reflect the nutrient input into the system. This could be the mass of nutrient applied as fertilizer, or as fertilizer plus manure and other materials, and it may also include deposition from the atmosphere, net release from soil reserves, and for N, legume fixation.
  - Depending on the purpose intended for the application of the indicator, manure nutrient sources and/or biologically fixed N may need to be considered. For field, farm, regional or national indicators, only PNB or PFP are able to be collected, as the others require unfertilized check plots and/or wide scale soil test values. Such nil fertilizer treatments are impractical and unreasonable for many small-scale farmers or landholders.
  - The availability of data for nutrient use by crop is limited at regional or national levels, although aggregated nutrient input data may be available. There is a need for transparent and publicly available data on the patterns of nutrient use by crop to determine both PNB and PFP. The fertilizer industry may assist with collating these data.
  - For intensity measurements, the area sown, the area harvested, the farmed area, the agricultural area or the total regional or country area could be the denominator, and possibly mask potential impacts.

Farm-level nutrient performance

Given that farm level interventions are the most likely to have impact, it is important to consider how nutrient performance is assessed on farm.

- **Fertilizer is used within a farming system**, which is most likely multi-crop, and may or may not include livestock. Particular fertilizer strategies may be used on one crop, and the subsequent field activity receives residual benefit from that activity. For example, P may be applied to cereal and oilseed crops, but the residual benefit to soil P also flows through to subsequent pulse crops such as field peas or chickpeas, which are more efficient at accessing soil P. Similarly, residual N from either prior pasture legumes or pulse crops is available to subsequent oilseed and cereals. So, the consideration of only one phase in a rotation or one field in a year will not account for residual fertilizer activity and so underestimate the amount removed in produce relative to the amount applied.
- **Fertilizer use is largely an agronomic decision** based on the response it provides in growth or yield. Responses occur when the nutrient or nutrients supplied are limiting production, and so their addition takes the yield towards its biophysical limit, which may be set by water, temperature, sunlight or other biotic and abiotic factors. A typical nutrient response curve (**Figure 1**) shows that yield increases initially strongly in response to added nutrient (A-B), but the amount of extra yield declines as further amounts are added (B-C)—the law of diminishing returns. Any additional nutrient added beyond the maximum yield (D) does not give additional yield and little additional uptake, and so does not give immediate economic returns and may result in soil accumulation or increased risk of loss to the environment. In some situations for N, yields may even decline with extra nutrient supply.
- **Nutrient performance indicators are derived from the response curve** (**Figure 1**) and they can be derived in various ways, either in cumulative or relative terms. Cumulative expressions such as PFP and PNB (removal/use ratio), are derived from the quotient of yield (PFP) or nutrient contained in the yield (PNB) and the amount of nutrient supplied (**Table 1**). Neither can be calculated for a nil application as the denominator is zero. Partial factor productivity answers the question "How productive is this cropping system in comparison to its nutrient input?" Partial nutrient balance answers the question "How much nutrient is being taken out of the system relative to the amount supplied?"

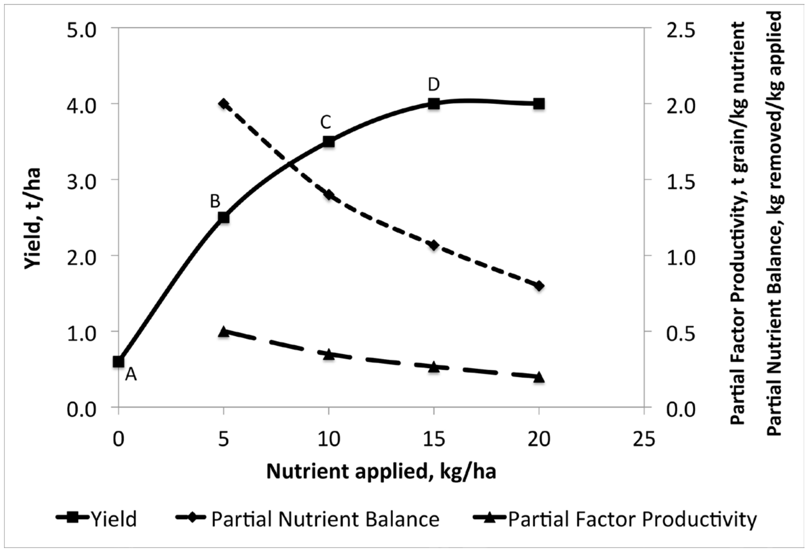

Figure 1. Example of crop yield, and the performance indicators of Partial Nutrient Balance (kg nutrient removed/ kg nutrient applied) and Partial Factor Productivity (t yield/kg nutrient applied). This nutrient balance illustration is based on a nutrient concentration of 4 kg nutrient per tonne of product.

- **PNB and PFP decline with higher rates. Figure 1** shows that as nutrient rate increases, marginal response decreases, so that if decisions about optimal rates were to be developed based on these terms alone, very low or no nutrients would be added. The consequence is that production would be substantially reduced and any nutrient removed would come from the soil reserves. The highest efficiency on the yield curve occurs where yields are the lowest, however effectiveness should not be sacrificed for the sake of efficiency. Higher nutrient efficiencies could be achieved simply by sacrificing yield, but that would not be economically effective or viable for the farmer. The utility of these particular indices depends on the type of data available as well as the purpose to which they are directed, and no individual indicator covers the social, productivity (economic) and environmental dimensions of sustainability.
- **For farmers, the amount of fertilizer to use is fundamentally an economic decision moderated by their attitude to risk**, and is largely based on the relative price paid for the nutrient and the price received for the produce. If the cost of nutrients is very low then the rates used would be higher than if the cost were higher. Alternatively, if the value of the produce is very low, there would be little incentive to use nutrients as there would be little return on even a small investment. However, if the value of the produce is high—either in commercial terms or in terms of food security—extra fertilizer will be added to move the yield potential towards its maximum. How closely that maximum yield is approached depends on the risk attitude and financial resources of the producer.
- **Better nutrient performance will rely on engagement with farmers.** This is clearly because the interventions appropriate will be made by farmers within the constraints of their production system. While rate is often mentioned as part of the decision, choice of the right nutrient source, applied at the right time and in the right place are also key parts of effective delivery of nutrients to meet the demand pattern of crops and pastures. Using 4R Nutrient Stewardship guidance will enable growers to better match nutrient supply

through adjusting source, rate, time and place to match the soil characteristics, climatic constraints, and the spatial and temporal demand of the cropping system; while also considering social and environmental goals (IPNI, 2012).

- **Need to collect farm level nutrient efficiency data.** Despite its importance, there are few measures of the farm level PNB or PFP, nor is the distribution of these values publicly available for regions or industries. Farm level surveys could assist in developing key management practices for improving both indicators, when linked to other aspects of nutrient performance.

A single performance indicator is not adequate to indicate system improvement. Table 2 shows an illustrative table of the estimates of PNB and PFP for cereal crops grown in selected countries and also a global value. The data for cereal production is derived for two periods (2006 and 2010) from FAO crop statistics database (FAOSTAT, 2014), and fertilizer use is derived from IFA surveys (Heffer, 2009; Heffer, 2013) for the same two years. Those two reports did not include all countries and reported here are those countries with fertilizer use by crop data for both selected years. The values presented are the means derived from these two sample years and the table encompassed 75% of the global cereal area and 86% of the global production. Grain N concentrations used in these calculations were derived from average values in the IPNI nutrient concentration database (http://info.ipni.net/IPNI-3296) and weighted for the proportions of crops produced.

The interpretation of these indicators is not as simple as “more (or less) is better” as the ratios expressed need to be interpreted in a similar way to the data from **Figure 1.** A very high PNB value indicates that more nutrient is being removed than added, and this may be of value where soil residual nutrient levels are high. On the other hand, a high PNB could indicate unacceptable depletion of soil nutrients, such as through the breakdown of soil organic matter. Alternatively, if the PNB is very low, where more nutrient is being applied than being removed, then this may be because the soil has a high binding capacity or that additional nutrient is required to build up soil nutrient levels. A very low PNB does not necessarily indicate that nutrients are being lost, as they may be used in subsequent phases of the farming system. In both cases, the impact of high or low PNB requires an understanding of the fate of the nutrients applied and unless indexed against soil fertility trends and climatic conditions, the number is of little value.

Similarly, the value of the PFP could also be very high or very low. A very high value—where there is a large quantity of production for the applied nutrient—really suggests that the native supply is very low and the system is operating at the steep part of the response function (**Figure 1**). Alternatively, a low PFP indicates that the system is operating at the flat part of the response function, and the gap between actual and achievable yield is small.

Therefore, while PNB and PFP provide some information about the efficiency and effectiveness of nutrient performance, unless they are considered with changes in soil fertility and the grain yield (or yield response to added nutrients), they convey little real information about system performance. Partial nutrient balance values lack critical information about nutrient fate or destination, so do not materially add knowledge about the environmental impact of fertilizer use. Similarly, PFP conveys limited system performance information as it inevitably declines as fertilizer rates increase, irrespective of real productivity.

There are opportunities to tie nutrient performance indicators to other data sources, which would help in their meaningful interpretation. For example, PNB could be linked to the current efforts in describing global soil carbon (i.e., organic matter) stocks, or to regional soil test values where those data are available (Fixen et al., 2014). Partial factor productivity could be linked to the estimates already being indexed as Indicator #10 (crop yield gap: actual yield as % of attainable yield) in the SDSN report (SDSN, 2014), although it would be important to discriminate the gap attributable to nutrients as other biotic and abiotic limits may operate to limit achievable yield.

Table 2. Cereal area and mean cereal yield, mean nitrogen application rate, and the performance indicators of Partial Nutrient Balance (kg nutrient removed/kg nutrient applied) and Partial Factor Productivity (t yield/kg nutrient applied). The Partial Nutrient Balance is based on a weighted cereal grain N content of 1.58% (*as is basis*).

	Cereal area, Mha	Mean cereal yield, t/ha	Mean N rate, kg/ha	N PFP, kg grain/kg fertilizer N	N PNB, kg N grain/kg fertilizer N
Argentina	9.24	4.37	57	77	1.21
Australia	18.37	1.39	27	52	0.82
Bangladesh	11.18	4.02	93	44	0.69
Brazil	18.42	3.63	54	67	1.06
Canada	15.95	3.26	74	45	0.71
Chile	0.59	6.41	179	36	0.57
China	83.14	5.48	172	32	0.50
Egypt	2.99	7.01	252	28	0.44
EU-27*	58.04	4.85	104	47	0.74
India	99.24	2.56	95	28	0.43
Indonesia	15.13	4.62	99	46	0.73
Iran	8.70	2.47	66	38	0.60
Malaysia	0.67	3.52	123	29	0.45
Mexico	10.01	3.36	79	42	0.67
Morocco	5.59	1.60	22	74	1.16
Pakistan	12.93	2.58	124	21	0.33
Philippines	6.73	3.21	45	71	1.12
Russia	40.54	1.87	25	84	1.32
South Africa	2.99	3.65	77	48	0.76
Thailand	11.32	3.00	43	73	1.16
Turkey	13.04	2.68	68	39	0.62
USA	52.86	6.69	144	47	0.74
Vietnam	8.36	4.96	106	47	0.74
World	**679.08**	**3.43**	**81**	**43**	**0.67**

** Disaggregated data for EU-27 member countries for fertilizer use by crop is not publicly available.*

The importance of nutrient best management practice

The indicators proposed reflect inputs and outputs, but nothing of the processes that farmers and their advisors use to guide and shape nutrient management through the use of best management practices. Since nutrient performance indicators relate to internal impacts within the farming system, they may respond in some instances more directly to improved practices than indicators more related to external impacts, such as edge-of-field nutrient loss or gaseous emissions. So tracking the adoption of those practices will provide more information on the progress improved stewardship than input and output ratios.

There is a global effort to develop and promote these best practices, and this dimension is one that should also be considered as an indicator of performance. This suggested indicator could be about the number of fields or farms that have documented nutrient management plans. These could be assessed within the 4R Nutrient Stewardship guidelines of matching the right source, applied at the right rate, at the right time, and in the right place. Other data, such as the use of soil testing, farmer training, or farm record keeping could also be complementary indicators of nutrient performance and used as evidence of the adoption of nutrient best management practices.

Conclusions

For broad scale nutrient use efficiency and effectiveness estimates, only PNB or PFP are most easily derived and provide some useful information, but neither are complete productivity or environmental indicators. These metrics need to be described in terms of the system boundary, the time scale used and the sources of the raw data used. The most appropriate performance indicator terms depend on the context in which they are to be applied. For regional nutrient risk assessments, a PNB will be of use, whereas to assess the effectiveness of nutrient use for food production PFP will be useful.

Partial nutrient balance is not able to identify nutrient loss processes or pathways and so is not an indicator of environmental fate. The rigorous identification and quantification of loss pathways is critical to understand the fate of nutrients not removed in harvested products; not a simple removal to use ratio used in isolation.

Neither PNB nor PFP are complete productivity indicators. While PNB can be interpreted in terms of anticipated changes in soil fertility, it gives no indication of current levels. While PFP gives yield per unit of nutrient applied, it does not indicate productivity per unit of land area, or land spared for other uses including nature.

The monitoring and reporting of the use of 4R practices can complement the reporting of nutrient performance, but additional practices and additional indicators are necessary to reflect the full range of social, economic and environmental impacts.

The use of a nutrient performance indicator in isolation is likely to be misleading in terms of how effectively and efficiently nutrients are being used. A more complete picture will require an assessment of the status of and changes in soil nutrient levels and an assessment of the magnitude of the gap between current yield and the yield possible when nutrients are non-limiting.

Appendix Table. Examples of nutrient performance measures and indicators as adapted from the 4R Plant Nutrition Manual (IPNI, 2012) aligned against SDSN Indicators.

Performance Measure or Indicator	Description	SDSN Proposed Indicator & Nominated Agency
Indicators mainly related to economic performance		
Yield	Amount of crop harvested per unit of cropland per unit of time (e.g., t/ha/y)	Goal 2 (#10) Crop yield gap (actual yield as % of attainable yield) (FAO)
Partial Factor Productivity	Yield of product per unit of nutrient applied. (e.g., kg grain/kg nutrient applied	Not mentioned, but could be adapted from #10 and #12.
Δ Yield – NPK	Yield increase attributable to added nutrients. (e.g., t/ha)	Goal 2 (#10) (part) Crop yield gap (actual yield as % of attainable yield)
Crop/Produce Quality	Sugar, protein, mineral, oil, vitamin or other attributes that add value to the product. (e.g., wheat grain protein concentration)	Goal 2 (#8) [Percentage of population with shortfalls of any one of the following essential micronutrients: Fe, Zn, I, Vit A, folate, B12. Indicator to be developed (FAO, WHO)
Net Farm Income	Return to farm operators for labour, capital and management after expenses. (e.g., $/ha)	Goal 8 (#59 in part) (per capita incomes) Net Farm Income is a subset of Gross National Income per capita (IMF, World Bank, UN Stats Div.)
Return on Investment	Profit in relation to capital investment. (e.g., $ return/$ invested)	Not specified.
Indicators mainly related to social performance		
Labor Use Efficiency	Labor productivity, linked to the number and timing of field operations. (e.g., labor unit/ha)	Possibly Goal 5 (#46) Ratification and implementation of fundamental ILO labor standards and compliance in law and practice
Food Security	Access to sufficient, safe, nutritious food to maintain a healthy and active life (e.g., ranking on global food security index)	Goal 2 (#7 & #8) Percentage of population below minimum level of dietary energy consumption (MDG Indicator) (WHO, FAO)
Adoption of Best Management	Fields or farms with documented nutrient management plans. (e.g., % of farms with nutrient budgets; % of farms 4R compliant).	Could be related to Goal 2 (#11) (part) Number of agriculture extension workers per 1000 farmers [or share of farmers covered by agricultural extension programs and services]
Indicators mainly related to environmental performance		
Partial Nutrient Balance (Nutrient Removal to Use)	Removal of nutrient in product per unit of nutrient applied. (e.g., kg nutrient removed/kg nutrient applied).	(Nitrogen) Goal 2 (#12) Crop nitrogen use efficiency (%) (FAO, IFA)

Water Quality	Nutrient concentrations and loadings in watersheds. (e.g., nitrate leaching to groundwater kg/ha/y; soil loss t/ha/y)	Goal 6 (#54) (part) [Reporting of international river shed authorities on trans-boundary river-shed management] - Indicator to be developed (UNEP, INBO, GEF). Goal 2 (#13) [Excessive loss of reactive nitrogen [and phosphorus] to the environment] - indicator to be developed (UNEP, INBO, GEF).
Air Quality	Nutrient concentrations and loadings in airsheds. (e.g., N_2O emissions kg/ha/y; ammonia emissions kg/ha/y)	Goal 3 (#34) (part) Mean urban air pollution of particulate matter (PM10 and PM2.5) (UN-Habitat, UNEP, WHO) Goal 13 (#85) (part) Net GHG emissions in the Agriculture, Forest and other Land Use (AFOLU) sector (t CO_2e) (UNFCCC)
Ecosystem Services	Services for provisioning, regulating and supporting systems, plus cultural benefits. (e.g., $ valuation of services)	Not specifically referenced, but implicit in several goals and indicators.
Biodiversity	Diversity of species within a system.	Goal 15 (#92) part Protected areas overlay with biodiversity (regional and global) (UNEP-WCMC)
Water Productivity	Crop harvested per cubic meter of water. (e.g., t/m^3) – important in water limited areas.	Goal 2 (#16) [Crop water productivity (tons of harvested product per unit irrigation water)] - Indicator to be developed (FAO)
Energy Use Efficiency	Energy used per t of crop harvested. (e.g., Gj/t)	Not considered directly but low carbon economy discussed under Goal 13.
Soil Fertility	Soil test values, such as N,P,K, organic matter. (e.g., mg/kg, %, frequency distributions)	Goal 2 (#15) Annual change in degraded or desertified arable land (% or ha). Not a complete assessment of soil fertility in this indicator.

AFOLU = Agriculture, Forestry and Other Land Use; FAO = Food and Agriculture Organization; IFA = International Fertilizer Association; GEF = Global Environmental Facility; ILO = International Labor Organization; INBO = International Network of Basin Organizations; MDG = Millennium Development Goals; UN = United Nations; UNEP = United Nations Environmental Programme; UNFCCC = United Nations Framework Convention on Climate Change; UNEP-WCMC = United Nations Environment Programme's World Conservation Monitoring Centre; WHO = World Health Organization.

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