Nutrient Use Efficiency and Factors Affecting It

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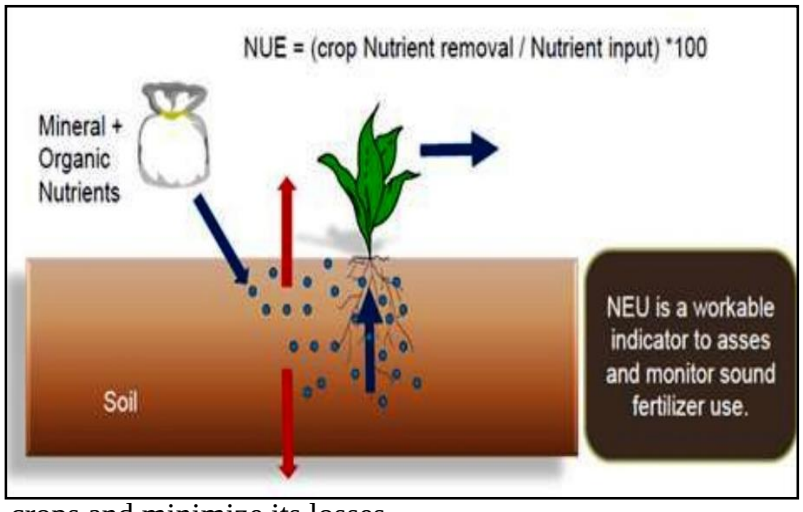
NUE is a critically important concept for evaluating crop production systems and can be greatly impacted by fertilizer management as well as soil- and plant-water relationships. NUE indicates the potential for nutrient losses to the environment from cropping systems as managers strive to meet the increasing societal demand for food, fiber and fuel. NUE measures are not measures of nutrient loss since nutrients can be retained in soil, and systems with relatively low NUE may not necessarily be harmful to the environment, while those with high NUE may not be harmless.

Nutrient/fertilizer use efficiency : Nutrient use efficiency is the fraction of fertilizer nutrients removed from the field with the crop harvest. The objective of nutrient use is to increase the overall performance of cropping systems by providing economically optimum nourishment to the crop while minimizing nutrient losses from the field and supporting agricultural system sustainability through contributions to soil fertility or other soil quality components. The most valuable NUE improvements are those contributing most to overall cropping system performance. Therefore, management practices that improve NUE without reducing productivity or the potential for future productivity increases are likely to be most valuable. At the same time, as nutrient rates increase towards an optimum, productivity continues to increase but at a decreasing rate, and NUE typically declines.The extent of the decline will be determined by source, time, and place factors, other cultural practices, as well as soil and climatic conditions. Interventions for improving nutrient use efficiency (N &P) Nutrient recovery can be improved through adoption of locally as well as scientifically available means of nutrient management to ensure efficient use of agricultural inputs (chemical fertilizers, land, water, and crops) that will enhance beneficial use of N and P in crops and minimize its losses.



Common Measures of NUE and their Application

An excellent review of NUE measurements and calculations was written by Dobermann (2007). Table 1 is a summary of common NUE terms, as defined by Dobermann, along with their applications and limitations. The primary question addressed by each term and the most typical use of the term are also listed.

- **Partial factor productivity (PFP)** is a simple production efficiency expression, calculated in units of crop yield per unit of nutrient applied. It is easily calculated for any farm that keeps records of inputs and yields. It can also be calculated at the regional and national level, provided reliable statistics on input use and crop yields are available. However, partial factor productivity values vary among crops in different cropping systems, because crops differ in their nutrient and water needs.
- **Agronomic efficiency (AE)** is calculated in units of yield increase per unit of nutrient applied. It more closely reflects the direct production impact of an applied fertilizer and relates directly to economic return. The calculation of AE requires knowledge of yield without nutrient input, so is only known when research plots with zero nutrient input have been implemented on the farm. If it is calculated using data from annual trials rather than long-term trials, NUE of the applied fertilizer is often underestimated because of residual effects of the application on future crops. Estimating long-term contribution of fertilizer to crop yield requires long-term trials.
- **Partial nutrient balance (PNB)** is the simplest form of nutrient recovery efficiency, usually expressed as nutrient output per unit of nutrient input (a ratio of "removal to use"). Less frequently it is reported as "output minus input." PNB can be measured or estimated by crop producers as well as at the regional or national level. However, since the balance calculation is a partial balance and nutrient removal by processes, such as erosion and leaching are usually not included. Also, all nutrient inputs are rarely included in the balance calculations, thus the modifier, partial, in the term.
- **Apparent recovery efficiency (RE)** is one of the more complex forms of NUE expressions and is most commonly defined as the difference in nutrient uptake in above-ground parts of the plant between the fertilized and unfertilized crop relative to the quantity of nutrient applied. It is often the preferred NUE expression by scientists studying the nutrient response of the crop. Like AE, it can only be measured when a plot without nutrient has been implemented on the site, but in addition requires measurement of nutrient concentrations in the crop. And, like AE, when calculated from annual response data, it will often underestimate long-term NUE.

- **Internal utilization efficiency (IE)** is defined as the yield in relation to total nutrient uptake. It varies with genotype, environment and management. A very high IE suggests deficiency of that nutrient. Low IE suggests poor internal nutrient conversion due to other stresses (deficiencies of other nutrients, drought stress, heat stress, mineral toxicities, pests, etc.).
- **Physiological efficiency (PE)** is defined as the yield increase in relation to the increase in crop uptake of the nutrient in above-ground parts of the plant. Like AE and RE, it needs a plot without application of the nutrient of interest to be implemented on the site.

Table 1 : Common NUE terms and their application (after Dobermann, 2007).

Term	Calculation	Typical use
Partial factor productivity	PFP = Y/F	As a long-term indicator of trends.
Agronomic efficiency*	AE = (Y-Y0)/F	As a short-term indicator of the impact of applied nutrients on productivity. Also used as input data for nutrient recommendations based on omission plot yields.
Partial nutrient balance	PNB = UH/F	As a long-term indicator of trends; most useful when combined with soil fertility information.
Apparent recovery efficiency by difference*	RE = (U-U0)/F	As an indicator of the potential for nutrient loss from the cropping system and to access the efficiency of management practices.
Internal utilization efficiency	IE = Y/U	To evaluate genotypes in breeding programs; values of 30-90 are common for N in cereals and 55-65 considered optimal.
Physiological efficiency*	PE = (Y-Y0)/ (U-U0)	Research evaluating NUE among cultivars and other cultural practices; values of 40-60 are common.

Where :

Y = yield of harvested portion of crop with nutrient applied;

Y0 = yield with not nutrient applied;

F = amount of nutrient applied;

UH = nutrient content of harvested portion of the crop;

U = total nutrient uptake in aboveground crop biomass with nutrient applied;

U0 = nutrient uptake in aboveground crop biomass with no nutrient applied;

*Short-term omission plots often lead to an underestimation of the long-term AE, RE, or PE due to residual effects of nutrient application.

Nutrients use efficiency of nutrients and its causes :

Nutrients	Efficiency (%)	Cause of low efficiency
Nitrogen	30 – 50	Immobilization, volatilization, denitrification, leaching with water
Phosphorous	15 – 20	Fixation in soils as Al–P, Fe–P & Ca–P
Potassium	70 – 80	Fixation in clay-lattice
Sulphur	8 – 10	Immobilization, leaching with water
Micronutrients (Zn, Fe, Mn, Cu & B)	1 – 2	Fixation in soils

Factors affecting fertilizer/nutrient use efficiency :-

1. Leaching (NO_3).
2. Gaseous losses (NH_3, N_2O, N_2).
3. Immobilization by chemical precipitation, adsorption on exchange complex and microbial cells.
4. Chemical reactions between various components in fertilizer during mixing, before application to soil.
5. Fertilizer characteristics : Time, type and method of fertilizer application.
6. Physical condition of soil : It is mainly depends on soil humidity and soil aeration factors.
7. Chemical condition of soil: This depends on the total and available nutrient in soil.
8. Biological condition of soil: This depends on the soil pH and soil temperature.
9. Type of Crop: Selection of crop depends on following factors-
    - Economical value of crop
    - Absorption capacity of crop
    - Metabolism of nutrients by crop

Therefore, for increasing the fertilizer/nutrient use efficiency it is very essential to keep in mind the type of sol, climate, selection of fertilizer and variety of crop. With the above, fertilizers should be used by selecting the best method of use from which maximum crop production could be obtained with less expenditure.