

The Mysteries (Myths) of Nutrient Use Efficiency

By David W. Dibb

Nutrient use efficiency (NUE) is often misunderstood...or misrepresented...if it is discussed as an isolated issue and not in the context of the efficiency of the total crop production system. It is important to remember that efficiency and economic viability of the total food production system are objectives within which the various components need to be optimized to achieve overall goals.

Where nutrients are purchased inputs, land is most often the primary limiting resource in terms of its availability. There are areas where more land could be brought into production, but most often those are marginal lands in terms of their production potential. Their exploitation would likely result in significantly increased costs in terms of pollution, loss of wildlife habitat, reduction of recreational areas, or elimination of other publicly perceived value. In other words, the most productive land is already being used. Thus, the most effective way of improving the system's efficiency is through continuous increases in yields. This will improve the efficiency of the system as a whole because the primary limiting resource (land) is more productive in terms of yield per unit farmed.

A classic crop response curve shows how NUE could be misrepresented or misinterpreted if the values and objectives of the system are ignored or forgotten. **Figure 1** illustrates the growth response of a crop to some needed input such as a deficient nutrient or nutrients. The Y-axis (vertical) represents a measure of potential yield, which would reach 100 percent if all necessary components were

available in optimum quantities. The X-axis (horizontal) represents increasing application of needed nutrient inputs, assuming all other inputs and resources are nonlimiting. If any inputs are less than optimum, the curve may appear to be similar, but will peak at a lower yield and may not have as steep a slope. Or, if an input causes toxicity if over applied, the curve would turn down soon after the peak. There are several other variations that could make a family of curves, all of which would be below this highest yield potential curve.

In **Figure 1**, point C is the yield produced with only 'native' fertility supplied by the soil. None of the limiting nutrients have been applied. Point C represents the situation in many developing countries where yields are low because soils are infertile due to natural weathering processes or because they have

Inputs and resources do not function in isolation in biological systems, even though their individual efficiencies can be measured.

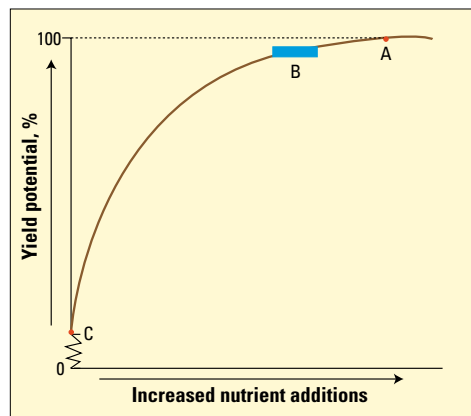


Figure 1. Classic crop response curve to added (limiting) nutrients.

been cropped for many years without replacing removed nutrients. Point A is the maximum yield potential at a given production site assuming all inputs are optimum. Point B is actually a range that depends on variables of cost and value which define the 'target' of the production system. This 'target' is where land use efficiency (LUE) is highest and where all other inputs and resources are interacting at their optimum level. It is just below the maximum yield potential. Within this range is also the economic optimum, where the greatest net return to inputs is achieved by the particular cropping system.

If we arbitrarily divide the response curve into four areas, we can discuss some general aspects of NUE and LUE and compare them for both developed and developing agriculture and see how some misconceptions may occur. We will label these areas I, II, III, and IV, from the bottom to the top of the response curve, illustrated in **Figure 2**.

Area I is at the bottom of the response curve. It is characterized by very low yields. Few nutrients are available or applied. Often the only nutrient application is through incorporation of limited crop residues or animal and human waste materials that may be available but not sufficient to move very far up the yield curve. Any addition of a limiting nutrient gives a relatively large response, as indicated by the steepness of the curve. Because yields are very low, LUE is very low. Environmental concerns are significant, since

crops grow poorly and slowly, exposing the land for long periods to severe water and wind erosion losses. Paradoxically, NUE can be very high, because any small amount of nutrient applied could give a large yield response. Thus, if NUE is the only goal, it could be achieved here, but people will continue to starve because of the low total production. Many countries can be characterized as being on this part of the curve. Sub-Saharan Africa is a good example. Dr. Norman Borlaug has described the situation where a modest increase of 20 to 30 lb/A more nutrients along with improved varieties has increased yields by two, three, or four times. Yet, these higher yields are relatively low. They are still on the steepest part of the yield curve.

Area II is a little higher on the yield curve, where agriculture begins to modernize, with new, higher yielding varieties that respond efficiently to nutrient inputs. Often there is an imbalance towards the use of nitrogen (N) to the exclusion or deficit of other nutrients...phosphorus (P) and potassium (K)...that could give additional response. While the yield curve has flattened a little, NUE may still be quite high for an individual added nutrient such as N, while other nutrients [P, K, sulfur (S), etc.] are being depleted from the soil. However, paradoxically, NUE can be lower than in Area I. Environmentally speaking, crop growth is not as vigorous as it could be; thus, wind and water erosion losses continue to be a big concern, and because N is used without proper balance with P and K, N loss potential can be large. LUE is not very good, because yields are well below the full potential that exists. India, which produces relatively low average yields versus the potential, might be in Area II. Nutrient use levels are only moderate, and there is considerable nutrient imbalance because of government policy decisions and economic availability. Many states from the former Soviet Union are falling back into this same area as they deplete their soils from lack of application of adequate nutrients, which has slipped to about 30 percent of former levels. Measured strictly by response to the meager levels of inputs now applied, the NUE may be quite high, but yields are declining, and

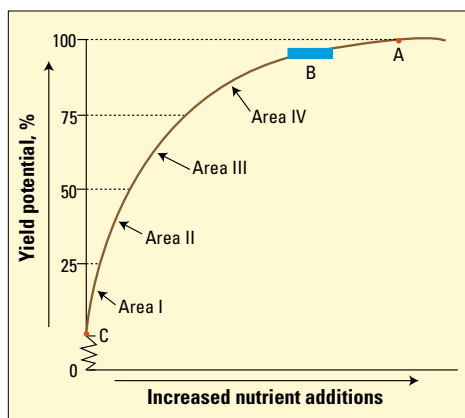


Figure 2. Nutrient use efficiency (NUE) and land use efficiency (LUE) are compatible.

future productivity is being robbed while LUE is dropping.

Area III is the part of the curve where there is still good response to added inputs. Yields are increasing, but the slope is less steep. In order to achieve these yields, improved balance in nutrient inputs must be observed, including additions of secondary [calcium (Ca), magnesium (Mg), and S] and micronutrients where deficient. Positive interactions among nutrients begin to take effect, and NUE improves. Plant growth is more vigorous, reducing potential wind and water erosion losses. More organic residue is produced, and with good management, erosion losses can be reduced even further. Because there is still some imbalance towards N, there is less than desirable efficiency of N use. China is a good example of a country that has moved in the last 10 to 15 years from Area II into Area III. They have worked hard to balance N-P-K ratios appropriately, including attention to secondary and micronutrients, and have seen yields increase accordingly. China has additional unrealized yield potential, is clearly moving up the yield curve, and will move further as nutrient input balance continues to improve. Nutrient use efficiency can be improved, but they have dramatically improved their LUE...and the economic return to the system from purchased inputs.

Interestingly, some production areas that were blessed with highly fertile soils started out in this Area III as their agriculture began to develop. Examples would be the Pampas of Argentina and the U.S. Midwest. In both places, crops were grown for many years without replacing nutrients that were being exported in harvested crops. Without attention to nutrient replacement, production will start to slip back from Area III to Area II. The U.S. started to pay attention to these deficits in the early 1950s as nutrient deficiencies began to be observed and corrected. Argentina is just beginning to go through this same transition, and nutrient applications are increasing.

Area IV is at the top of the yield curve. With attention to nutrient balance,

NUE can be quite high while at the very top of the yield curve. LUE has reached its highest level. Crops grow vigorously and help protect the soil from wind and water erosion. Large amounts of crop residue are produced and, with proper management, can help to minimize or even eliminate erosion losses. If yields are moved into 'range' B, the economic optimum is also achieved, helping assure the sustainability of the system.

One might conclude that developed agricultures of North America and of Western Europe fall into this category...and they probably do. However, they still struggle with environmental concerns such as erosion losses and N and P in surface and ground waters, as well as economic viability. Why is this? In part, because most farmers are at the top of Area III or bottom of Area IV, and improvements can still be made. Whether through better nutrient balance and timing of application to improve NUE, or better management of crop residues to reduce erosion losses, or use of buffer strips to intercept potential nutrient losses, or myriad other decisions to increase yield and improve efficiency, farmers are trying to make improvements.

Few farmers achieve much higher than 75 or 80 percent of yield potential...even in the developed world. They are starting to use new tools, which have been referred to as part of 'precision agriculture' or, more accurately, 'site-specific management'. All of these changes improve NUE to acceptable levels for a sustainable production agriculture that provides adequate food, fiber, feed, and fuel for all parts of the world. This is true NUE which resides in Area IV, not Areas I, II, or III, on the yield curve. NUE is optimized as a part of the total production system which maximizes LUE and economic return to all inputs...while protecting the environment. These components will define and determine sustainability now and for the future. **BC**

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