Fertilizer requirements for specified yield targets. I. Theoretical derivation of mathematical models for the computation of soil and fertilizer nutrient efficiencies

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Abstract. The conventional deduction procedure of computation of soil (\(x\)) and fertilizer (\(\beta\)) nutrient efficiencies for the amount of fertilizer required for specified yield targets does not make provision of the amount of soil nutrient derived by crops from the available pool of soil nutrients not accounted for in the amount extracted by a soil test procedure. The derivation of two mathematical models, viz., Tamil Nadu Agricultural University Model I [TNAU Model I] and Model II [TNAU Model II] is reported in this paper which aim at computing the soil (\(x\)) and fertilizer (\(\beta\)) nutrient efficiencies not accounted for by the conventional method.

In the case of TNAU Model I, the relationship between the nutrient uptake (U) and the soil (S) and the fertilizer (F) nutrients was established by assuming a functional relationship of the type \(U = xS + \beta F\) such that \(0 \leq x \leq 1\) and \(0 \leq \beta \leq 1\). In TNAU Model II the same relationship was established as \(U = xS + \beta F + \gamma\) such that \(0 \leq x \leq 1, 0 \leq \beta \leq 1\) and \(\gamma > 0\). The term \(\gamma\) in the latter model is a measure of the amount of soil nutrient the crop absorbs from a slowly available pool of nutrients not accounted for in the amounts extracted by the soil test procedure employed or applied through fertilizer.

The field verification of these models is reported elsewhere.

The amount of fertilizer required for specified yield targets [7] for varied soils and climatic regions has evoked considerable interest in India in recent years [1, 5], since they ensure both high yields and maintenance of soil fertility to support a sustained crop production. The soil nutrient efficiency (\(x\)) and fertilizer nutrient efficiency (\(\beta\)) along with the nutrient requirement (NR) are the essential parameters necessary for determining the amount of fertilizer required for specified yield targets [5]. Under the conventional deduction procedure [5], these parameters are calculated using the crop response data as follows:
Nutrient requirement (NR) = \frac{\text{Total uptake of the nutrient by the crop (kg ha}^{-1})}{\text{Yield of economic produce of the crop (in any convenient measure ha}^{-1})}

Soil nutrient efficiency (\alpha) = \frac{\text{Total uptake of the nutrient in the control plot (kg ha}^{-1})}{\text{Soil test value of the nutrient in the control plot (kg ha}^{-1})}

Fertilizer nutrient efficiency (\beta) = \frac{\text{Total uptake of the nutrient in the treated plot (kg ha}^{-1}) - \text{Soil test value of the nutrient in the treated plot (kg ha}^{-1})}{\text{Amount of the nutrient applied through fertilizer in the treated plot (kg ha}^{-1})}

The average value computed for the values of NR obtained from all the plots of the experiment is the quantity of the nutrient the crop requires for the production of a unit quantity of economic produce. The average \alpha value is computed for the values of \alpha obtained from the control plots of the experiment and is the efficiency of available soil nutrient measured by a given soil test method. The average \beta value is computed for the values of \beta obtained from all the treated plots and is the efficiency of added fertilizer nutrient. These three parameters are used to relate (Y) with soil (S) and fertilizer (F) nutrients as follows:

NR Y = \alpha S + \beta F

which on rearrangement,

F = \frac{1}{\beta} (NR Y - \alpha S)

This equation serves as the basis for working out the fertilizer nutrient dose (F) for a given soil test value (S) and specified yield target (Y).

In this conventional deduction procedure, however, deriving the fertilizer required with respect to a particular nutrient is not possible when the computed value of either \alpha or \beta is less than zero or more than one, for the efficiencies of soil and added nutrient can never be less than zero or more