Mapping Nutrient Budgets within Fields
Paper 1368

T.S. Murrell, H.F. Reetz, Jr. and Q.B. Rund

ABSTRACT

Nutrient budgets indicate if the amount of nutrients removed by crops has been exceeding, keeping up with, or falling behind nutrient additions. These budgets can be calculated spatially from nutrient application and yield maps. Maps of recent soil tests and target soil test levels provide the basis for evaluating the appropriateness of the budgets. Budget evaluation maps help farmers visualize which areas of the field are meeting soil nutrient management objectives and which are not, leading to improved nutrient management strategies for future crop production.

INTRODUCTION

What is a nutrient budget?

A nutrient budget compares nutrient inputs and nutrient outputs on a field area. The nutrients we are concerned with in this paper are phosphorus (P) and potassium (K). Inputs include fertilizer, manure, and in some areas, atmospheric deposition (for K). Outputs, or nutrient losses from the field area, include erosion, runoff, and removal in harvested plant portions. When estimating nutrient budgets in production settings, most agronomists use a partial budget, considering only the manure and fertilizer inputs and the crop removal output.

A partial nutrient budget is simply calculated by summing all of the inputs and subtracting all of the outputs. In the partial budget discussed above:

[1]   (fertilizer + manure additions) – crop removal

Equation 1 implies that a positive budget is one where inputs > outputs. In this case, soil test P and/or K levels would be expected to increase. Conversely, a negative budget is one where inputs < outputs and would be associated with declining soil test levels. A nutrient budget where inputs are approximately equal to output is called "balanced".

Whether positive, negative, or balanced budgets are agronomically appropriate depends on recent soil test results. Soil test levels are compared to those targeted by farmers and advisers to optimize crop production and manage economic and environmental risks. **Table 1** summarizes how nutrient budgets can be evaluated by recent soil tests. The management corrections suggested are not quantified. They simply identify that re-evaluations of the P and K fertility program must take place. Even where no management correction is identified, farmers and advisers still need to discuss if management is proceeding according to plans.

Assembling the Project Data

In our example, we will use data from a field in central Illinois. Corn was grown in 2001 and 2003 and soybeans were grown in 2002. Applications of P and K were made in the fall of 2000, 2001, and 2002. These applications were made prior to the subsequent cropping season. The data collected are listed in **Table 2**.

Field boundary
The field boundary layer was obtained from an ATV equipped with a GPS receiver and mapping software. The ATV was driven around the field and the geo-referenced path recorded.

Table 1. Interpretation of nutrient budgets with a recent soil test. The measured soil test levels are compared to target levels.

Budget	Measured soil test level compared to the target soil test level	Management correction needed?	Type of management correction needed
Negative	Below target	Yes	Increase inputs
Negative	At target	Yes	Increase inputs
Negative	Above target	No	
Balanced	Below target	Yes	Increase inputs
Balanced	At target	No	
Balanced	Above target	Yes	Decrease inputs
Positive	Below target	No	
Positive	At target	Yes	Decrease inputs
Positive	Above target	Yes	Decrease inputs

Table 2. Types of data required for calculating nutrient budgets within fields.

Layer	Source	Format
Field boundary	Farmer/adviser	Shapefile
Geo-referenced, cleaned yield maps	Farmer/adviser	Shapefile
Estimates of nutrient removal rates by crops	Farmer/adviser/scientist	Farmer/adviser plant analysis records; university extension publications
Geo-referenced nutrient application maps	Farmer/adviser	Shapefile

Geo-referenced yield maps
Yield data were collected from a yield monitor installed on a harvester. Coupled to the monitor was a GPS receiver. Distributions in data were analyzed and obvious outliers, like low to null yields at the ends of rows, were omitted.

Estimates of nutrient removal rates by crops
There were two sources of these data in our example. In 2001, corn grain was sampled by hand from georeferenced locations in the field, prior to machine harvesting. Grain samples were sent to a soil testing and plant analysis laboratory. Lab results were converted to P and K removal rates per harvest unit (lb P_2O_5 or K_2O per bushel of grain).

For subsequent crop years in our example, standard estimates of P and K nutrient removal rates were used (Hoeft and Peck, 2002). For corn, these were 0.43 lb P_2O_5/bu and 0.28 lb K_2O/bu. For soybeans,

nutrient removal estimates of 0.85 lb P_2O_5/bu and 1.30 lb K_2O/bu were used. These estimates were multiplied by yield to calculate nutrient removal per acre:

[2]   Nutrient removal (lb/acre) = yield (bu/acre) x nutrient removal rate (lb/bu).

For instance, 200 bu/acre of corn is estimated to remove:

[3]   200 bu/acre x 0.43 lb P_2O_5/bu = 86 lb P_2O_5/acre.

Nutrient application maps
In our case, we used maps of nutrient recommendations. This introduced error in our calculations, because we assumed that the rates recommended were those actually applied. Georeferenced layers of rates "as applied" and monitored by application equipment would have been preferable.

Spatial data was organized using ArcCatalog and a new Personal Geodatabase created (named KDNNew, Figure 1). All shapefiles were exported into the geodatabase. During the export procedure (right click on shapefile name then Export | Shapefile to Geodatabase), settings were changed, and coordinate systems were changed to an appropriate, consistent, projected coordinate system using feet as the linear measurement unit.
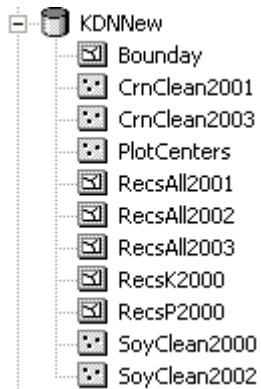

Figure 1. Personal geodatabase created for the project data.

ANALYZING THE DATA

Creating Rasters

Spatial Analyst was used to create rasters of all of the shapefiles listed in Figure 1. A common cell size of 30 ft. was used for all rasters. Nutrient application maps were created from the following set of commands: Spatial Analyst | Convert | Features to Raster…. Yield and soil test information came from point data and required interpolation (Spatial Analyst | Interpolate to raster | Inverse distance weighted). A Power of 2 was selected, and 12 points used as the Search Radius Setting.
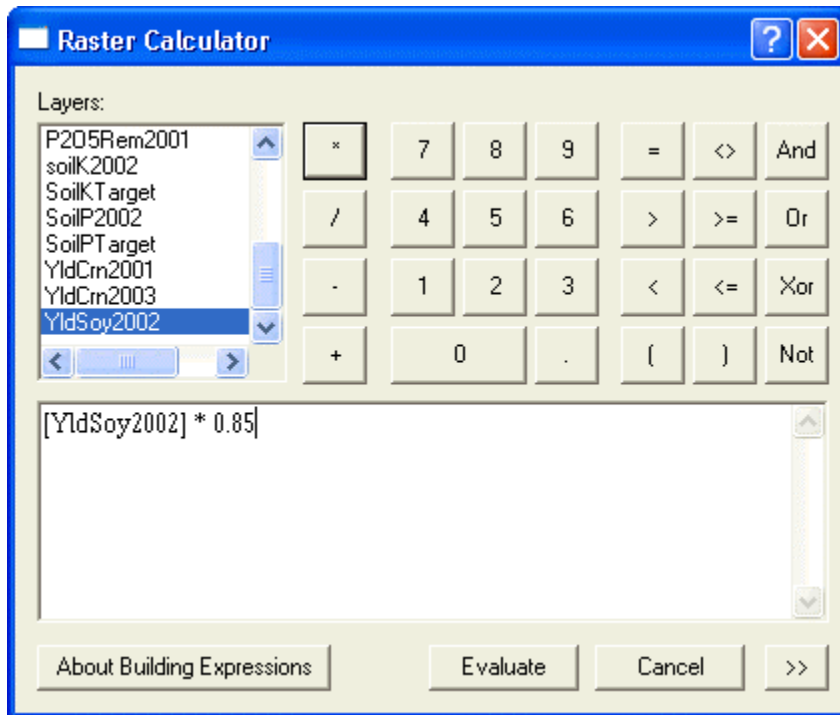

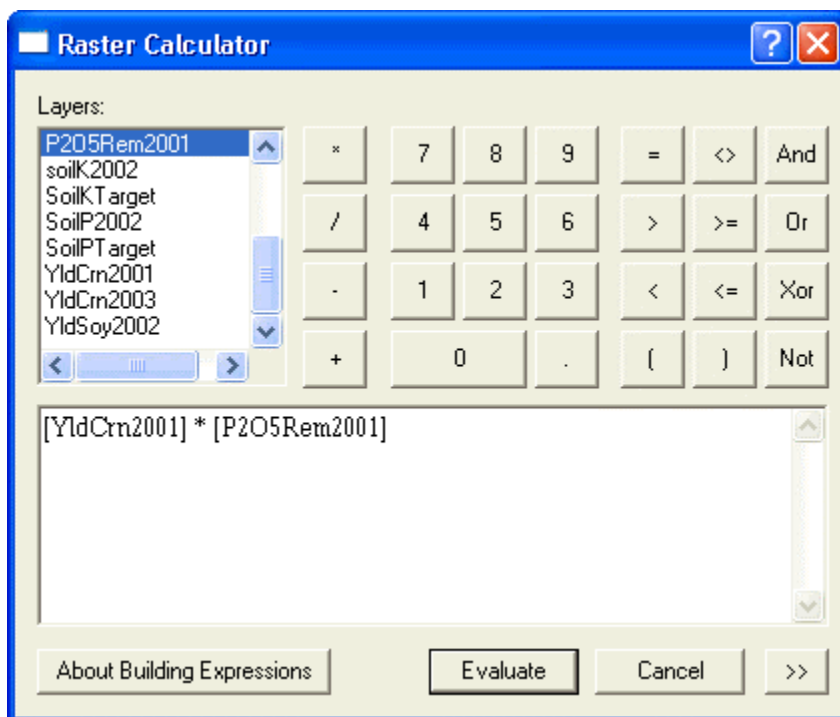## Creating and Evaluating Spatial Nutrient Budgets

Inputs
Nutrient recommendation rasters from each year, created in the above step, provided the input data.

Outputs
Raster calculator (Spatial Analyst | Raster calculator) was used to multiply yield rasters by generalized estimates of nutrient removal (discussed above). This created rasters of nutrient removal for crop years 2002 and 2003.

Raster Calculator

Layers:
P2O5Rem2001
soilK2002
SoilKTarget
SoilP2002
SoilPTarget
YldCrn2001
YldCrn2003
YldSoy2002

[YldSoy2002] * 0.85

About Building Expressions   Evaluate   Cancel   >>

For 2001, grain samples taken from georeferenced locations in the field were analyzed and the data converted to a raster of P and K nutrient removal rates for corn (named P2O5Rem2001 and K2ORem2001, respectively). This locally collected nutrient removal raster was multiplied by the corn yield data raster from 2001.

Raster Calculator

Layers:
P2O5Rem2001
soilK2002
SoilKTarget
SoilP2002
SoilPTarget
YldCrn2001
YldCrn2003
YldSoy2002

[YldCrn2001] * [P2O5Rem2001]

About Building Expressions   Evaluate   Cancel   >>

Coding partial nutrient budgets

Partial nutrient budgets rasters were created according to Equation 1. Rasters of recommended rates from each year were added together. Nutrient removal rasters were added together and subtracted from the sum of the annually recommended rate rasters. This provided a net nutrient budget for the P and K applications and crop harvests during a 3-year production cycle.
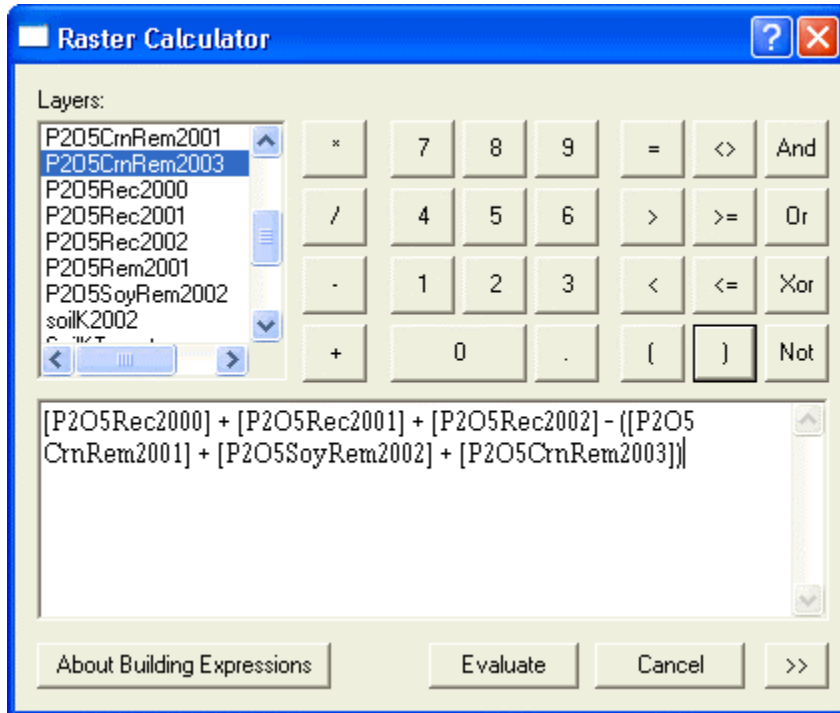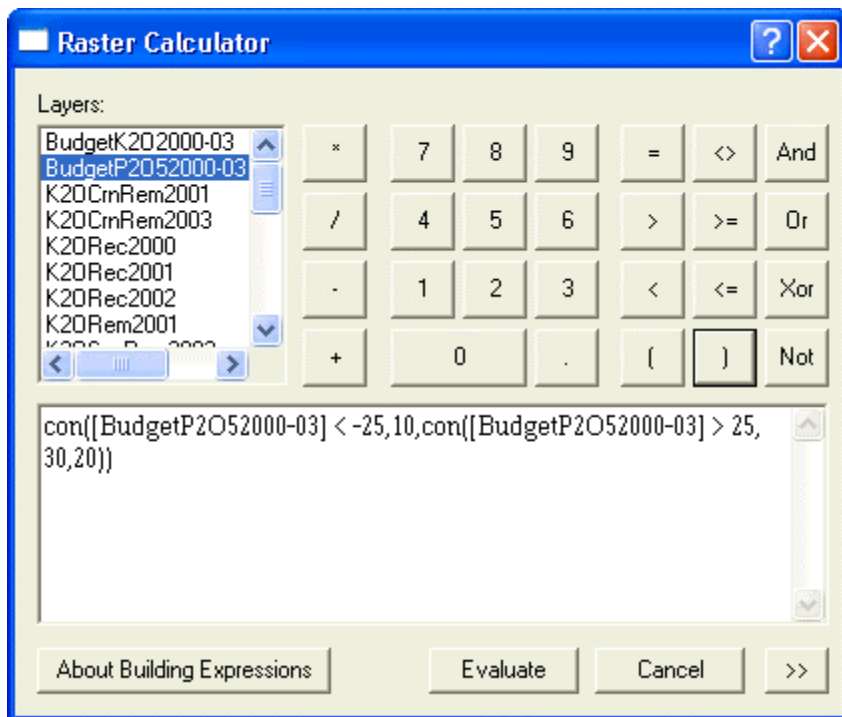

Nutrient budgets were coded with a:
- "10" if they were negative (inputs < outputs)
- "20" if they were within $\pm$ 25 lb P_2O_5 or K_2O of being balanced (inputs approximately equal to outputs
- "30" if they were positive (inputs > outputs).

The "con" function in Raster calculator was used to accomplish this task. The generalized form of the "con" function is:

$$con(condition, result\ if\ true, result\ if\ false).$$

We used a nested "con" function (see graphic below). The first part of this function tests if the budget raster is less than a -25 (the lower end of our tolerance bracket for a balanced nutrient budget). If it is less than -25, then a code of "10" is assigned. The "result if false" is another "con" statement. In this statement, we state that if the budget raster is greater than 25 (the upper end of our tolerance bracket for a balanced budget), then a code of "30" is assigned. The "result if false" in the second statement assigns a code of "20" if the raster is not beyond either extreme in our tolerance range. Another way of stating this is that "20" is assigned to all cells falling within the tolerance range of a balanced nutrient budget.

In this way, we were able to assign the 3 codes to the nutrient budget rasters for both P and K.


☐ ☑ BudgPCode
   Value
   ■ 10
   ☐ 20
   ■ 30
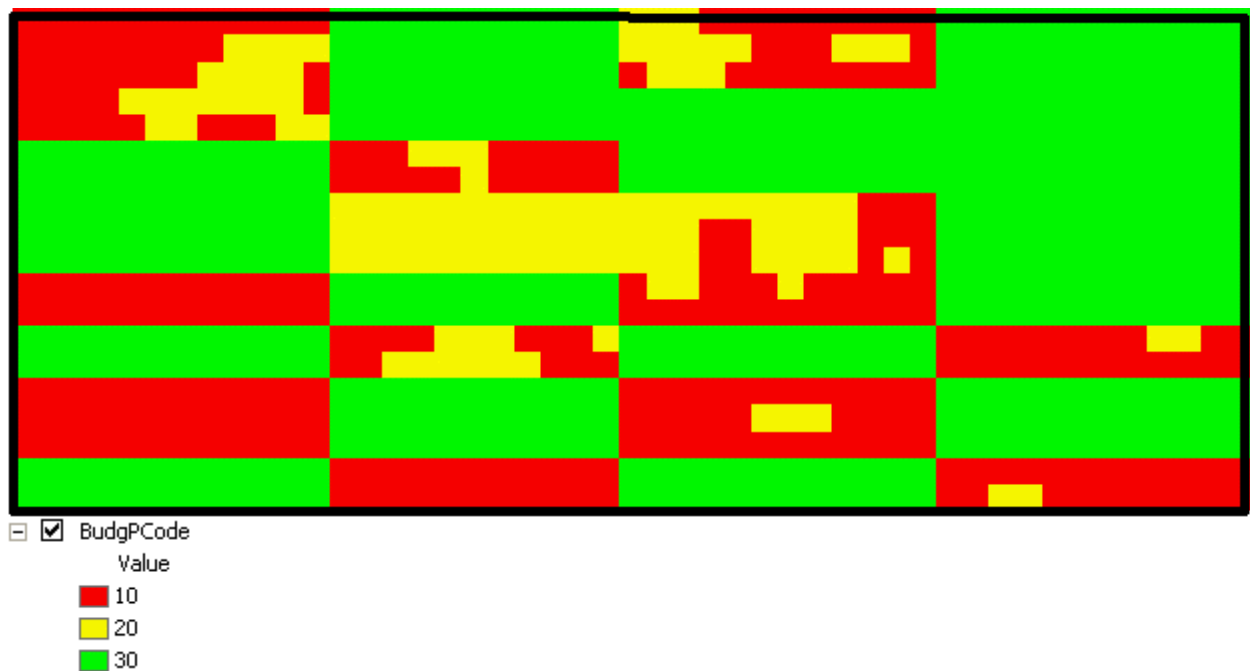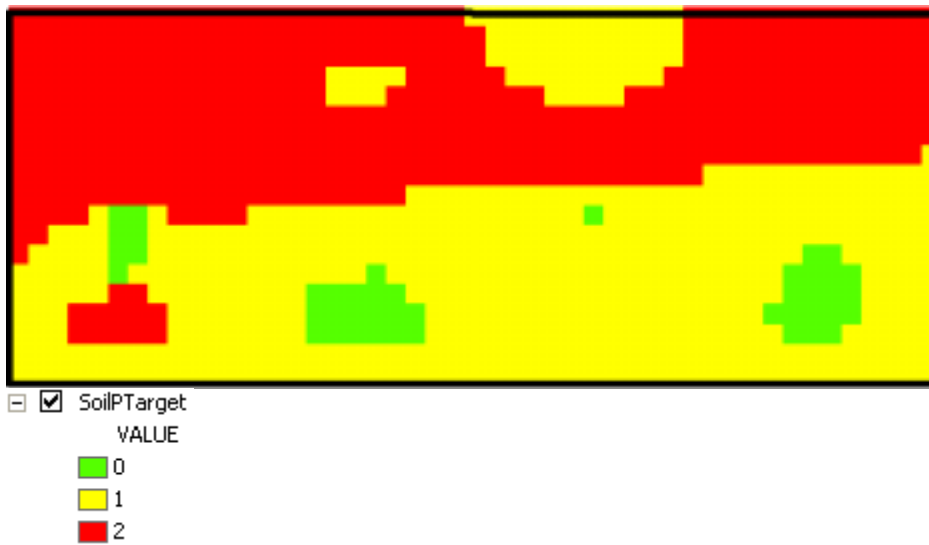
Coding soil test data
Measured soil test levels were compared to soil test levels targeted by the farmer and his/her adviser. The following codes were implemented:

- "0" if measured soil tests were below target levels
- "1" if measured soil tests were within a 15 lb/A tolerance for P or a 50 lb/A tolerance for K
- "2" if measured soil tests were above target levels

The "con" function was employed as it was for the nutrient budget rasters, explained above.
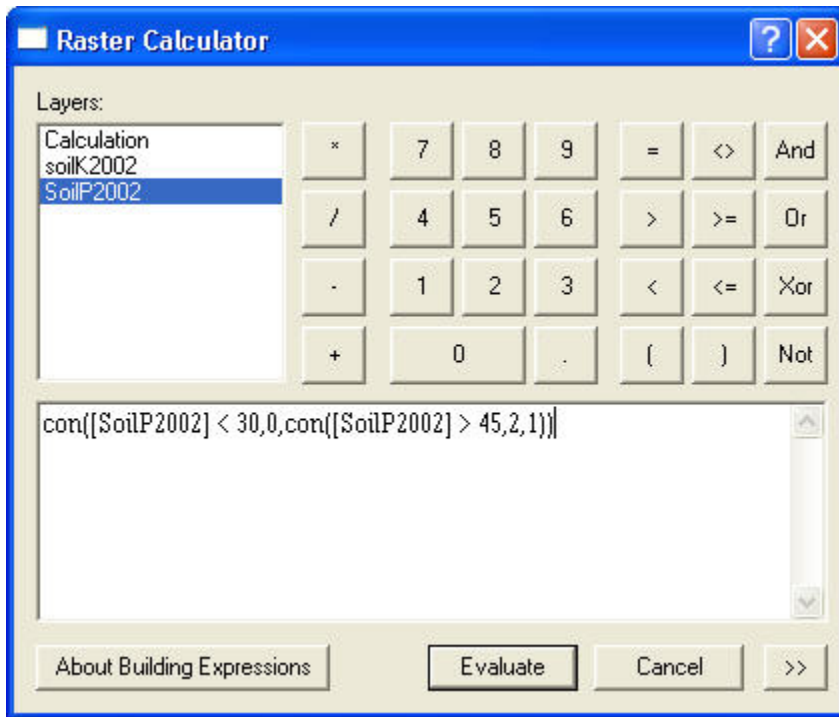
This resulted in coded maps for P and K soil test data.

Coding nutrient budget evaluations
As explained in the beginning of this paper, nutrient budgets must be evaluated with a recent soil test. Efforts up to this point have been to code both partial nutrient budgets and soil test data. We used Raster calculator to add the budget codes to the soil test codes to create a combined code.
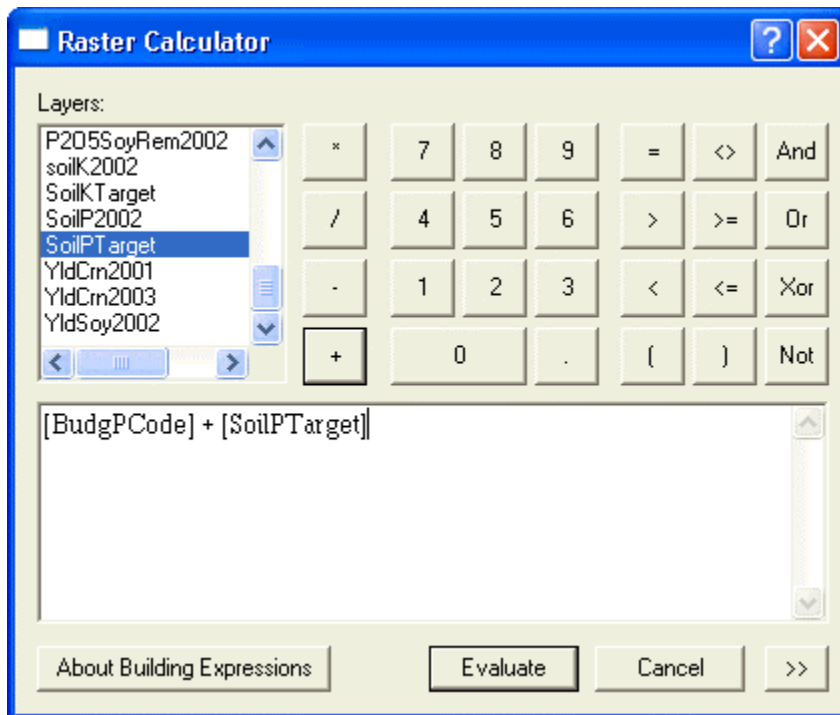

This combined code is interpreted in Table 3 (below).

Table 3. Coded nutrient budgets and coded soil tests. The combined code interprets nutrient budgets with the soil test information.

Budget	Budget code	Measured soil test level compared to the target soil test level	Soil test code	Combined code	Management correction needed?	Type of management correction needed
Negative	10	Below target	0	10	Yes	Increase inputs
Negative	10	At target	1	11	Yes	Increase inputs
Negative	10	Above target	2	12	No	
Balanced	20	Below target	0	20	Yes	Increase inputs
Balanced	20	At target	1	21	No	
Balanced	20	Above target	2	22	Yes	Decrease inputs
Positive	30	Below target	0	30	No	
Positive	30	At target	1	31	Yes	Decrease inputs
Positive	30	Above target	2	32	Yes	Decrease inputs

Symbology for these layers was chosen in two ways. The first color scheme used red or green only. Red represented areas where a management correction, identified in Table 3, was needed. Green represented areas where nutrient budgets were qualitatively appropriate (in the right category), given the soil test levels.
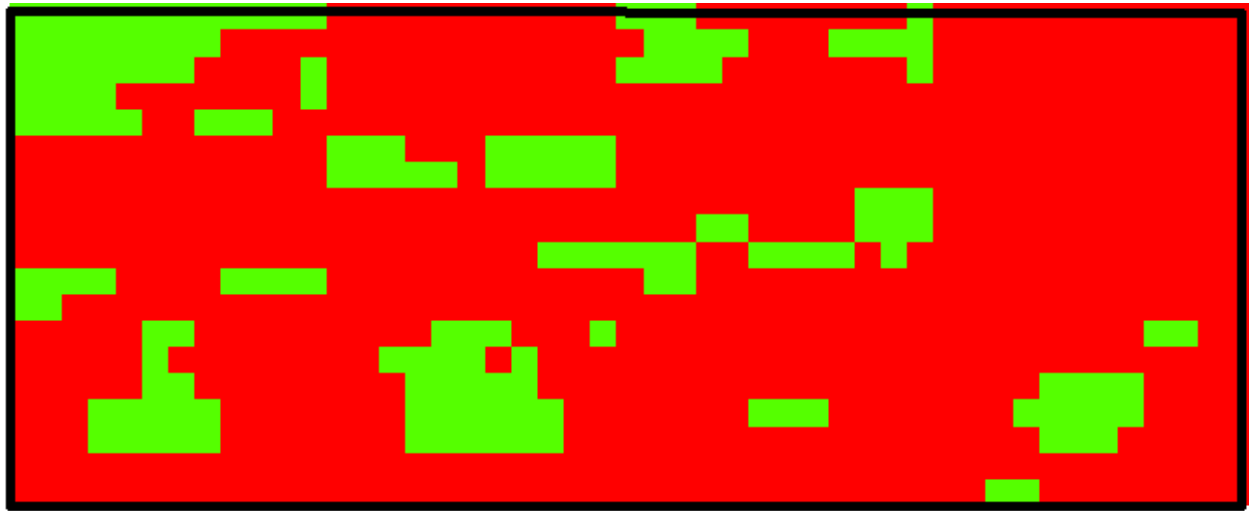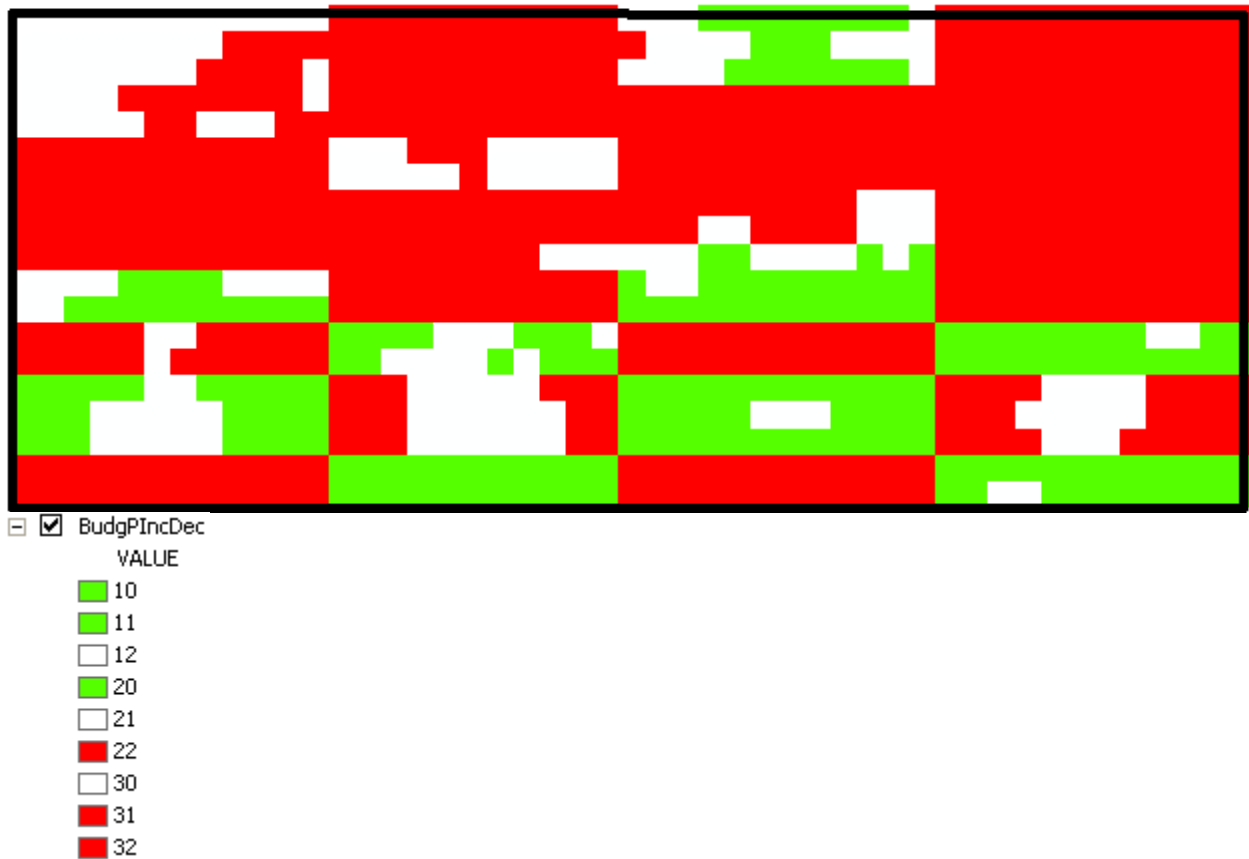

☐ ☑ BudgPEvalCorr
   VALUE
   ■ 10
   ■ 11
   ■ 12
   ■ 20
   ■ 21
   ■ 22
   ■ 30
   ■ 31
   ■ 32

The second symbology used for the combined coding raster was white, red, and green. White denoted areas where no alteration was qualitatively needed in rates. Green marked areas requiring some increase in input level. Red indicated the need for input reductions.

BudgPIncDec

VALUE

- 10
- 11
- 12
- 20
- 21
- 22
- 30
- 31
- 32

SUMMARY

Procedures were presented for analyzing yield, soil test, and nutrient application data to calculate and evaluate nutrient budgets. A method of coding was introduced that facilitated budget evaluations by creating management decision categories. These categories signaled areas where changes needed to be investigated to align nutrient budgets more closely with soil fertility management objectives.

ACKNOWLEDGEMENTS

REFERENCES

Hoeft, R.G. and T.R. Peck. 2002. Soil testing and fertility [Online]. p.91-131. In 2003-2004 Illinois Agronomy Handbook. Univ. Illinois Coop. Ext. Serv., Univ. of Illinois, Champaign. Available online with updates at http://www.ag.uiuc.edu/iah/ (verified 18 May, 2004).

AUTHOR INFORMATION

T. Scott Murrell
Northcentral Director
Potash & Phosphate Institute
3579 Commonwealth Rd.
Woodbury, MN 55125
Phone: (651) 264-1936
Fax: (651) 264-1928
Email: smurrell@ppi-far.org

Harold F. Reetz, Jr.
President
Foundation for Agronomic Research
107 S. State Street, Suite 300
Monticello, IL 61856
Phone: (217) 762-2074
Fax: (217) 762-5688
Email: hreetz@ppi-far.org

Quentin B. Rund
PAQ Interactive Inc.
803 West Williams St.
Monticello, IL 61856
Phone: (217) 762-7955
Email: qrund@paqinteractive.com