ORGANIC FARMING RESEARCH FOUNDATION

Project Report Summary

NUTRIENT MANAGEMENT IN ORGANIC GRAIN AND VEGETABLE SYSTEMS

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On-farm nutrient budgets in organic cropping systems: a tool for soil fertility management

It is extremely challenging for organic producers to manage soil fertility so that the correct balance of nutrients is applied to maintain food quality and yield while avoiding over-application. One strategy that could contribute to organic nutrient management is application of a mass balance approach to budgeting nutrients.

Construction of simple mass-balance budgets at the field or farm scale involves quantifying inputs and harvested exports. Typically, N, P and potassium (K), and other nutrients are brought into the farm in purchased soil amendments or feed for livestock. Additionally, N is imported from two other sources: N fixation by legumes, and to a lesser extent, from atmospheric deposition in the form of precipitation. Nutrients that originate from mineral sources such as P and K are also made available by the process of weathering or mineral solubilization.

Nutrients leave the farm in harvested crops and through unintended losses such as leaching and soil erosion. Nitrogen is also lost to the atmosphere through ammonification and denitrification. The amount of nutrients leaving the farm as unintended losses is determined by the size of the surplus and the capacity of the agroecosystem to store surplus nutrients. In other words, excessive applications of nutrients, particularly nitrogen, tend to increase the size of nutrient losses.

Long-term studies of organically managed cropping systems indicate that yields comparable to conventionally managed systems can be achieved under organic management while N surpluses are very small and N losses are

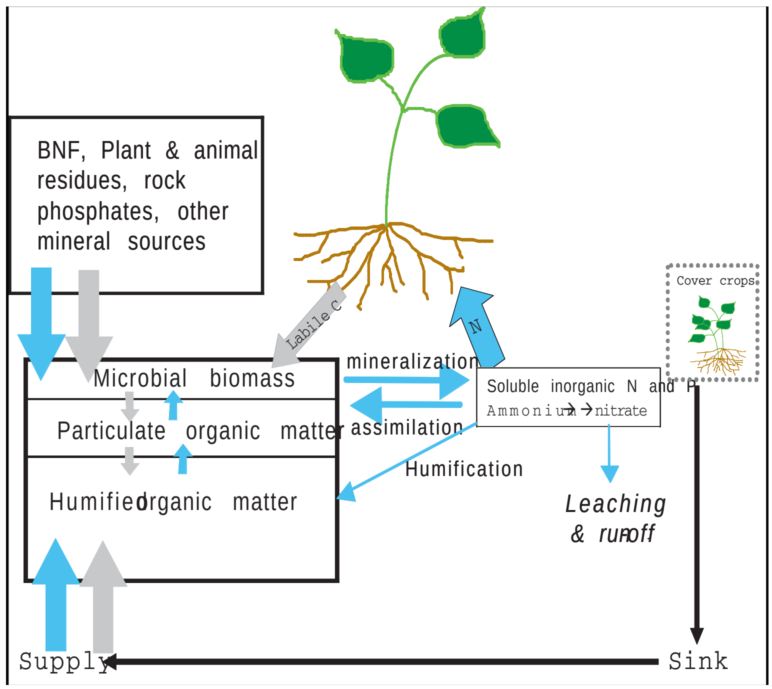

Fig. 1 Conceptual model of nutrient additions, reservoirs and relative fluxes under organic management. (*See note on figures, page 3.*)

significantly reduced. In these studies, under conditions of surplus N additions, a greater proportion of total N inputs was retained in the soil. Thus, organic production systems clearly have the capacity to operate close to a balanced state, something which has not been achieved in fertilizer-driven systems.

While these simulated research-based systems demonstrate the potential for organic management to meet yield goals without surplus nutrient additions, studies of organic farms indicate that the balance between nutrient additions and nutrients harvested in the crop varies tremendously due to large variations in nutrient additions

Studies of European organically-managed commercial farms found that grain systems

Project Notes

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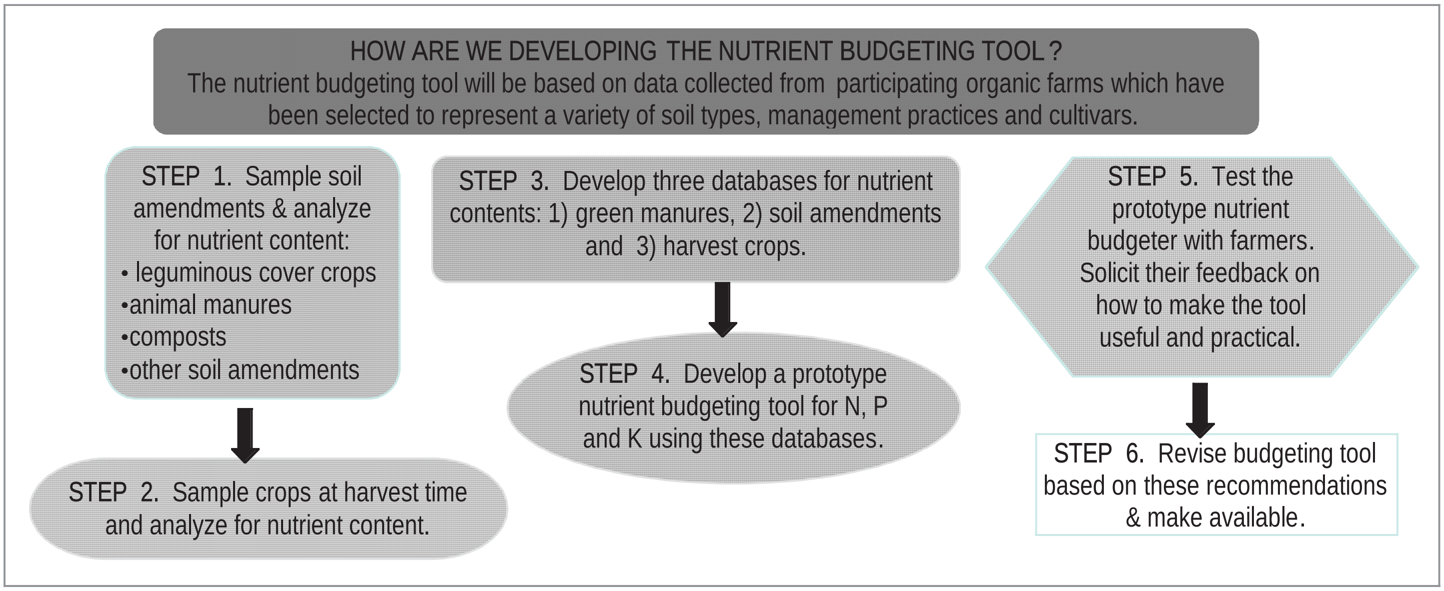

Fig. 2 Diagram of the steps involved in developing the nutrient budgeting tool and supporting databases.

operate with smaller N surpluses (2 to 50 kg N ha-1 yr-1) compared to horticultural crops with surpluses of 90 to 400 kg N ha-1 yr. Nutrient budgets constructed for multiple years that reflect rotation cycles for organic management units will provide a foundation for soil management recommendations that will improve efficiency, reduce costs and reduce the potential for environmental losses of nutrients.

Methods

We began working with local organic farmers in 2001 to develop the nutrient budgeting tool and supporting databases tailored to the farming systems. These databases are useful in conjunction with the nutrient budgeting tool or on their own as aids in soil fertility decisions. The three supporting databases are as follows:

1) The Green Manure Database is a set of conversion tables for green manures and their N content based on green manure stand size, derived from cover crop and green manure samples collected over three years (2002-2004) on twelve farms.

2) The Soil Amendment Database is a compilation of the nutrient content of external nutrient sources commonly used by organic farmers in the Northeast. Compost and manure samples were collected from 16 farms over two years (2003-2004).

3) The Grain and Vegetable Crop Database contains nutrient content for grain and vegetable crops. Vegetable samples were collected during four growing seasons (2001-2004) from 41 fields on seven vegetable farms in New York and Pennsylvania. Twenty-five types of vegetables were collected, which included approximately 150 different varieties. Grain samples were collected over two years (2002-2003) from 51 fields on eight farms in New York. Grain crops collected include: corn, soybean, wheat, oats, spelt, barley and triticale.

Nutrient Budgeter

A prototype nutrient budgeting tool was developed and linked to the databases described above. The original tool, in Excel spreadsheet format, was tested with farmers in January, 2004. Farmers' suggestions were then used to revise the budgeter. Nutrient budgets were constructed for two fields at Martens' Organic Grain Farm, one field at Myer's Organic Grain Farm, and sample rotations at Beech Grove Farm and Blue Heron Farm.

Nutrient Budgets Developed

We constructed sample single-year budgets for 11 farms using the budgeting tool and supporting databases. Nutrient balances in these organic systems are highly variable but we found that it is more common for vegetable production systems to be managed with large surplus additions of P and N due to the heavy reliance on compost for nutrients. [Figures 6 and 7 show the average annual rate of accumulation or depletion for N and P for model nutrient budgets for the 11 farms which were studied. Nutrient budgets showing annual changes in mass balances during a 5-year rotation for a sample vegetable and a grain farm are presented in Tables 2 and 3.]

The prototype budgeting tool was subjected to evaluations by several participating farmers in January, 2004. The farmers' responses were very favorable.

Results

We found some striking differences between vegetable and grain systems in terms of farm and field-scale nutrient balances. The tendency for small surpluses or deficits in grain farms compared to significant surpluses of varying sizes for vegetable farms is consistent with the findings of the

European study [conducted by Watson et al. (2002; see Fig. 6, Tables 2 & 3).]

Nitrogen was applied in the highest surpluses on vegetable farms with 50% of the farms exhibiting N excesses averaging 50 lbs/year or more.

Phosphorus also showed a tendency towards excess on vegetable farms, again especially among farms applying high rates of compost. Four vegetable farms as well as two of the grain farms achieved average annual P balances near zero, which probably reduces these farms' impact on local watersheds and may have additional benefits for the production system such as reduced susceptibility to diseases and weeds. Interestingly, one grain farm also had a high annual rate of accumulation of phosphorus, traceable to the large amounts of dairy manure with an especially low N:P ratio that are available to this farm from local sources.

Discussion

While land application of composted organic manures and wastes remains an excellent use of local resources for organic farmers, our simple mass balance analysis of the nutrient flows for a sample of leading organic farms points to the need to educate farmers and extension staff about appropriate and strategic use of such amendments, as well as risks of over applying nutrients that are mobile and can pollute local watersheds. The fact that a number of both grain and vegetable farms are achieving profitable yields without large surpluses of P and N supports the idea that organic systems have the potential to operate with very high nutrient use efficiency. The budgeting tool is most useful in identifying farming systems with significant imbalances and can be used in making decisions about the quantities of soil amendments that should be added to a rotation to replace exported nutrients. Farming systems that are generating small surpluses or deficits will need to combine budgeting with soil tests and crop performance considerations in order to accurately assess whether or not adjustments are needed. We conclude that using the mass balance approach can be an extremely useful and cost effective tool in conducting a first assessment of nutrient status of crop production systems.

Note on figures: *Laurie Drinkwater's project report includes seven figures and three data tables. Figures 1, 2, 6 and 7 are provided here. Please refer to the full report at ofrf.org for additional data.*

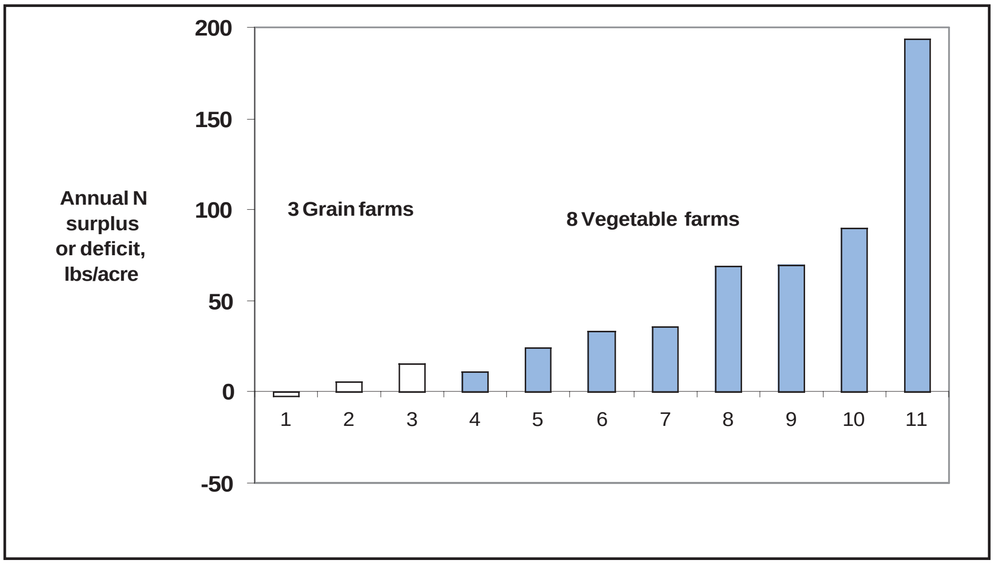

Figure 6. Nitrogen mass balances for sample fields in three grain farms (white bars) and eight vegetable farms (solid bars). These were calculated by dividing the final nutrient balance of the estimated budget by the number of modeled years (usually between 5 and 7 years). A given farm usually did not rank the same way for different nutrients (i.e. "farm 9" for N is not the same farm as "farm 9" for P).

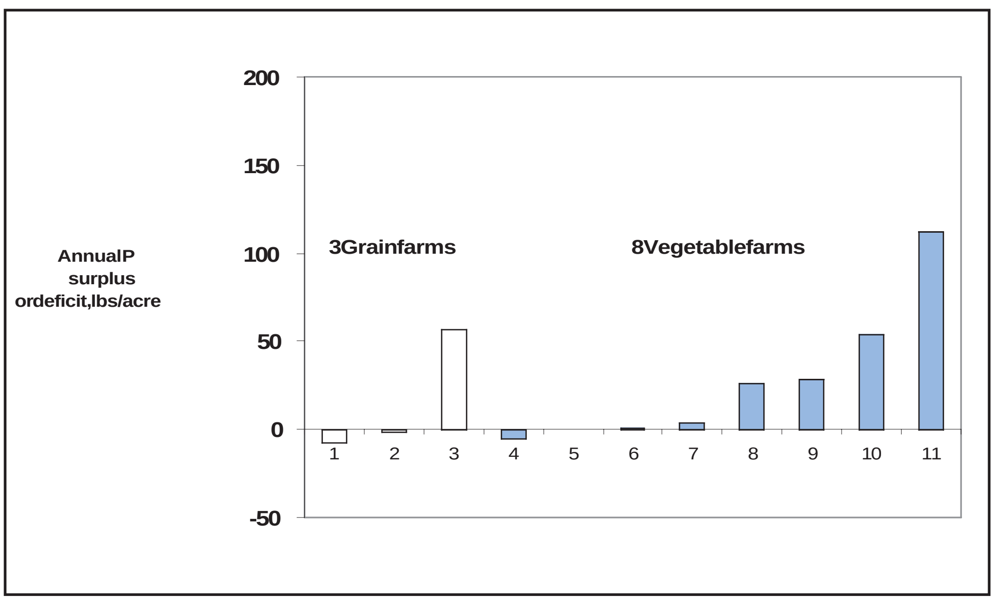

Figure 7. Phosphorus mass balances for sample fields in three grain farms (white bars) and seven vegetable farms (solid bars)ranked within category.

Note on tables: *Laurie Drinkwater's complete project report includes seven figures and three data tables. Tables 2 and 3 showing the results of nutrient budgets for typical fields from vegetable and grain farms are shown here. Please refer to the complete project report at ofrf.org for additional data.*

Table 2. Sample budget for one typical field in a vegetable farm. This farm is representative of typical soil fertility management practices that rely on significant compost inputs and generate large surpluses of nutrients. About half the vegetable farms showed signs of chronic over application of nutrients relative to harvested exports.

Year	Crop	Input source	N export (lb/ac)	N input (lb/ac)	N balance (lb/ac)	P export (lb/ac)	P input (lb/ac)	P balance (lb/ac)
1	winter squash	poultry litter compost	39	336	297	18	416	398
2	potato	vetch + poultry litter compost	107	7 + 336	236	29	416	387
3	lettuce	buckwheat	32	0	-32	5	0	-5
4	beets	vetch + poultry litter compost	53	7 + 336	290	9	416	407
5	broccoli	vetch	83	7	-76	11	0	-11
5-YEAR BALANCE					**+ 715**			**+ 1176**

Table 3. Sample budget for a typical field from one of the grain farms showing that the balances shift from positive to negative throughout the rotation cycle.

Year	Crop	Input source	N export (lb/ac)	N input (lb/ac)	N balance (lb/ac)	P export (lb/ac)	P input (lb/ac)	P balance (lb/ac)
1	corn	Fertrell GSS + poultry litter compost	96	4 + 34	-59	25	4 + 14	-7
2	soy	Fertrell Blue High K	0	1	1	8	0	-8
3	spelt	no inputs	55	0	-55	10	0	-10
4	corn	clover	65	111 + 4	50	17	4	-13
5	soy	Fertrell Blue High K	0	1	1	9	0	-8
5-YEAR BALANCE					**-62**			**-46**

Laurie Drinkwater's complete project report (17 pages, including references and additional data figures) is available at ofrf.org. ■