**Future of Food Course, Module 5**

**Worksheet, summative assessment for Module 5.2 on soils:**

Calculating nutrient budgets for management of nitrogen and phosphorus in two different systems.

**After completing the worksheet, use it as a guide to take the Summative Assessment quiz.**

**Introduction and description of the activity:**

The last page of module 5.2 mentions the twin issues of deficit and surplus that are principal challenges in the management of soil nutrients. This exercise allows you to use real data on nutrient inputs and outputs from two systems to create nutrient balances and analyze the situation of nutrient balance or surplus. These systems are the Ohio River sub-basin of the Mississippi River basin, and a farms from a typical smallholder region in the Bolivian Andes.

Use the data in Table 1 to create the balances for nitrogen (N) for the Ohio River basin and for phosphorus (P) in the Bolivian Smallholder example, according to the blanks given below the table (numbered sections 1 through 9 on pages two and three).

**Table 1**: Nitrogen flows related to agricultural management and atmospheric deposition in the Mississippi river basin, and management-related phosphorus (P) flows in an Andean smallholder system. The figures in the table are given as kg N or P entering or leaving a unit hectare (ha) of land (a hectare is 100 x 100 m)

**NOTE**: the columns for the different systems show ***different*** nutrients, N vs. P. below we will discuss how to compare the different balances given that they are for different nutrients.

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| --- | --- | --- |
|  | **Nitrogen (N) in Ohio River basin (Mississippi tributary)[[1]](#footnote-1)** | **Phosphorus (P) in Bolivian smallholder system[[2]](#footnote-2)** |
| Animal manure (input) | 4.5 | 4.2 |
| Fertilizer (input) | 44.9 | 0 |
| Atmosphere – rain, dust, lightning (input) | 10.3 | 0.2 (estimate; from dust) |
| Legume N fixation (N input, not a phosphorus source) | 14.6 | 0 |
|  |  |  |
| Crop Export (output) | 31.9 | 2.6 |
| Soil Erosion (output) | 4 (estimate based on typical erosion rates) | 5.5 |

1. Using the data in Table 1, calculate the Nitrogen Inputs and Outputs for the Ohio River Valley different systems – e.g. numbers reflecting flows such as manure, fertilizer, erosion from Table 1. by filling in the blanks in the below balance equations (you may not need all four blanks for each part of the balance):

Ohio River N input total: \_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_ + \_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_ (total N in, kg N/ha)

Ohio River N outputs: \_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_ + \_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_ (total N out, kg N/ha)

Now find the balance by subtracting outputs from inputs: \_\_\_\_\_\_\_\_\_ (N partial balance)

This balance is called an **N *Partial* balance** because we can’t find or measure **all** the data or balance information or *terms* of the balance – for example, we didn’t use any data on leaching or gas losses (See Fig. 5.2.3 in the online module). We are just using the terms that reflect human system impacts, like fertilizer applications and harvest, and a few others where we can find fairly trustworthy estimates. The idea is that we have enough information to find out whether human management is likely to create a large surplus that will pollute waterways (or contribute to global warming via N2O emissions); or conversely, create a deficit that will deplete the soil nutrient “bank account” and lead to diminished yields.

1. What is your conclusion regarding this balance? Is it likely to lead to water pollution impacts, reduced yields over time, or other impacts? (answer in a few words)

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1. Now calculate a similar partial balance for phosphorus (P) in the Andean system from Table 1 (you may not need all four blanks for each part of the balance):

Bolivia P input total: \_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_+ \_\_\_\_\_\_\_ + \_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_ (total P in, kg P/Ha)

Bolivia P outputs: \_\_\_\_\_\_\_\_+\_\_\_\_\_\_\_\_+ \_\_\_\_\_\_\_ + \_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_ (total P out, kg P/Ha)

Now find the balance by subtracting outputs from inputs: \_\_\_\_\_\_\_\_\_ (P partial balance)

1. What is your preliminary conclusion regarding the P partial balance from the Bolivian case? An excess likely to cause pollution, or a shortage that will reduce food production over time?

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1. How should we compare these two balances? The short answer is that we can’t really do so in a rigorous way. This is partly because one is N and the other P, and the point is not to compare apples with oranges, so to speak, but to compare our rough conclusions regarding deficit or surplus in each case. However, we don’t really know yet if the answers we got are large or small compared to some standard of “high” or “low” for deficits or surpluses. To further “benchmark” our estimates we use the following strategy: We can compare the balance to the amount of N or P in the harvest of a typical crop, which is information that we do have as part of each balance we calculated. The typical yield flow of N or P creates a natural benchmark to which we can compare each loss or surplus; In addition, to deal with the difference between N and P in the balances we can also consider the fact (generally known to plant and soil scientists) that in all the flows of nutrients like harvest, manure, or erosion, typically there is ***very*** roughly 10 times more N than P as a ratio within plant material, manure, soil etc. (ranging anywhere from 5 to 20 times approximately) – so the larger numbers we see for N than for P are due to this larger percentage of N than P in plant material rather than some large difference in harvest flows or manure between Ohio versus Bolivia. Based on these strategies above try these simple comparisons to gauge how serious each surplus or deficit is:
2. For each case (Ohio River Basin, Bolivia) calculate the ratio of the final partial balance to the corresponding flow of N or P in the crop harvest of each balance respectively:

Ratio of N balance to N harvest flow in the Ohio River Case: \_\_\_\_\_\_\_\_ / \_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_

Ratio of P balance to P harvest flow in the Bolivia Case: \_\_\_\_\_\_\_\_ / \_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_\_

1. Now state whether you think the surpluses or deficits are likely to create pollution or harm yields in the future, that is, use the ratio calculated in (6) to benchmark your balance estimate:
	1. Ohio River N balance: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
	2. Bolivia hillside agriculture P balance: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Now compare the amount of N and P lost as erosion, in comparison to the harvest flow of N and P in each case. In which system was erosion a more important nutrient loss pathway (remember **benchmarked to the harvest flow of N or P respectively)**

***Additional information*** to add to the discussion: It is useful to think about how these cases of surplus and deficit arose. For the Ohio N balance case, although we have presented N fertilizer in terms of its large energy cost, to many conventional grain farmers in the United States fertilizer applications may represent a fairly typical “fact of life” that actually do not have a very great cost within the production budget of a typical cash crop. Meanwhile, the *perceived risk* of not putting enough N fertilizer on and having lowered yields is high, because farmers operate on small margins – they make little money per acre (hectare) on their farm, so there is a pressure to gain maximum yields and expand this small margin, versus risking lowered yields. These pressures can lead to applying well over what the crop needs, knowing that sometimes only about half of what is applied as N reaches the crop. This lack of urgency around N use and pollution far from these farms is changing however. Many farmers have been focused on sustainable practices already for years, and increasingly farms and state/regional governments are making efforts to reform management methods to reduce N pollution.

Meanwhile, in the Bolivian case, farmers may be aware of the losses of nutrients from their soils, but they can do little to either stop erosion, or boost phosphorus inputs to compensate for the losses from their soils. This is explained by the resource-poor situation in which farmers find themselves, where their considerable efforts to grow food and occasionally sell some of it are not compensated to the same degree as farmers in wealthier areas. The high erosion rates also may be due to lack of access to credit that might allow them to make investments in reducing erosion, and the relatively marginal land they own that forces them to farm on steep hillsides which are more prone to erosion.

1. From Carey, A. E., Lyons, W. B., Bonzongo, J.-C., & Lehrter, J. C. (2001). Nitrogen budget in the Upper Mississippi River watershed. *Environmental & Engineering Geoscience*, *7*(3), 251–265. [↑](#footnote-ref-1)
2. Vanek, S. J., and L. E. Drinkwater. "Environmental, social, and management drivers of soil nutrient mass balances in an extensive Andean cropping system." *Ecosystems* 16.8 (2013): 1517-1535. [↑](#footnote-ref-2)