Managing soil fertility in the tropics

Building common knowledge: Participatory learning and action research

Chapter 4: Nutrient flow analysis

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Chapter 4

Nutrient flow analysis

In the two previous chapters we have given much room to a fundamental aspect of farming; living and developing means that we constantly move soil fertility, and do so over ever increasing distances.[1] The verbs *transport*, *transfer*, and *transform* are key words to describe what is happening.

We paid considerable attention to the fact that understanding the ensuing complexity calls for appropriate and practical frameworks. However, since any framework describing a complex issue necessarily simplify it, it is important that users appreciate its limitations. It can be difficult to analyse resource flows because the data is often imprecise; yields cannot always be measured, so they are often estimated, as is the amount of manure applied to fields. And because we normally cannot afford to routinely analyse the chemical content of every source, the nutrient content of sources and flows of fertility (soils, plants, manure, grain, crop residues, etc.) are often estimates based on relevant documentation. The situation is further muddied by the fact that we know that there can be considerable variation in the nutrient content of these sources.

Having noted its methodological limitations, we will now discuss how to use the analytical framework to understand various aspects of agriculture. The nutrient flow analysis framework is first of all meant to help field practitioners (agricultural researchers, extension staff and farmers) measure resource flows. This should improve their understanding of soil fertility management and enable them to make more informed decisions. For example, the framework should enable them to answer questions such as: "What will happen if two tons of grain is removed from a particular area every year, but the soil is not fertilised?" or “What are the possible solutions to remedy this particular situation?” Measuring and quantifying flows may thus be helpful in the context of assisting African farmers in soil fertility management.

This chapter describes how to analyse nutrient flows using an approach based on **balance** or **book-keeping**, (see framework presented in Tables 3.1 and 3.2, Chapter 3.)[2] As explained earlier, the basis for analysis are those processes that are comprehensible to any user of the land, that relate to farmers’ actions while managing their farm and considering the cost and time involvement required for measuring and quantifying. The resulting nutrient balances are therefore considered as

partial balances, and basically show what farmers take out of the system, and what they put back.[3] When the nutrients extracted roughly equal the nutrients brought back we assume that the system is in **equilibrium**. A large positive or negative difference is cause for concern and will require some form of corrective action. Nutrient **accumulation** occurs when more nutrients are added than removed, such as when kraals are used year after year without being properly cleaned out, or if human manure deposited in deep pit latrines. A **negative** balance means that the production system is being degraded as the store of available soil nutrients is depleted.

4.1 Analysing nutrient flows at farm-level

To facilitate the analysis of the functioning of a farm system and its nutrient flows, it is useful to first make a picture of the system and flows studied. This can be especially helpful when scrutinising farmers' made resource flow maps and systemising all information included (see Chapters 6 and 7).

The procedure outlined below will enable users to analyse a farm system and its flows in a relatively short space of time. The analysis will become more precise as the quality and quantity of data increases. However, it is not necessary to have a complete set of data at the outset. It is best to start with whatever is available and to gradually improve and complete the picture as more information comes available.

The procedure consists of four steps:

(1) Draw the major elements of the farm system on a sheet of paper, paying particular attention to different stocks and sources of fertility. Where possible, group the stocks and sources of fertility into sub-systems and identify their respective boundaries (Figure 4.1);

(2) On the next sheet of paper draw the resource flows that link the different elements or sub-systems of the farm system (Figure 4.2);

(3) Copy the second drawing onto a third sheet and complete the picture by adding in the measured or estimated resource flows (Figure 4.3);

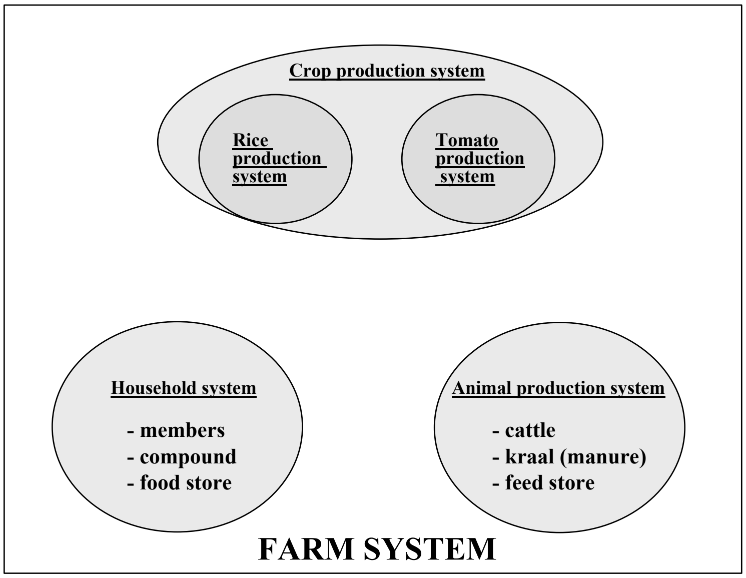
(4) Use a fourth sheet to show the estimated amount of nutrients within each resource flow. When translating quantities of matter into quantities of nutrients look at the data base drawn-up under local conditions or at the Tables in Chapter 3 (Figure 4.4).

This procedure will now be explained in detail using a hypothetical example.

Visualising the farm system

Figure 4.1 visualises a hypothetical farm system that includes three sub-systems. These are:

- the *household system,* which includes the compound where people live, also food stocks and possibly latrines;
- the *animal production system*, which includes various categories of animals, and a kraal with stored manure and feed stores;
- the *crop production system*, which in our example includes two sub-systems: the rice production system and the tomato production system.



Rice production system: 0.75ha; tomato production system: 0.25ha
cattle: 5 TLU (Tropical Livestock Units)

Figure 4.1 Visualising the farm system

Figure 4.1 shows that the sub-systems are part of the higher level farm system. The systems' boundaries are shown by a line drawn round the elements that belong to it. The boundary around the farm system marks the beginning of the outside world, over which the farmer has little or no control. The outside world contains markets, communally managed grazing land and woodland exploited for fuel wood and other forest products.

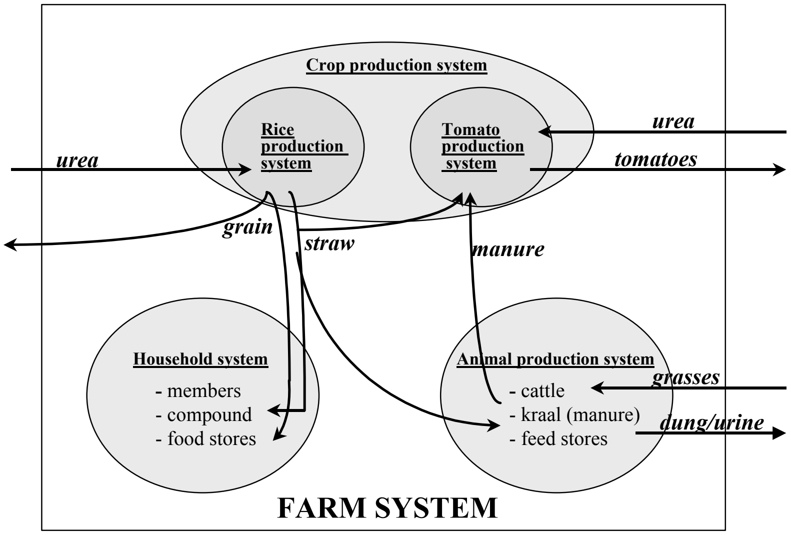
The hierarchy of the system visualised in Figure 4.1 is outlined below:

- the farm system is part of the larger village land use system;
- the farm system is made up of 3 sub-systems: the household system, the animal production system and the crop production system;
- the household system is composed of family members living in the compound and their food store;
- the animal production system includes cattle equivalent to 5 Tropical Livestock Units (TLUs), a kraal and a feed store;
- the crop production system is composed of 2 sub-systems: the rice production system and the tomato production system, which have fields of 0.75 ha and 0.25 ha respectively. (Note that the hypothetical farm has only 1 hectare of productive land).

Identifying resource flows

Having visualised the farm system we can now draw the resource flows entering and leaving it, as well as the flows between its various elements and sub-systems. Figure 4.2 shows the major resource flows in our hypothetical farm. Urea is the only source of mineral nutrient input into the crop production systems. Manure is used exclusively on the tomato plots, whose produce is sold; while the rice is either eaten by the household or sold at market. Rice straw has three main uses: as roofing material for the compound, as animal feed and as mulch on the tomato plots.

For the sake of simplicity, cattle do not graze on the farm fields after the harvest. Only a certain



Rice production system: 0.75ha; tomato production system: 0.25ha
cattle: 5 TLU (Tropical Livestock Units)

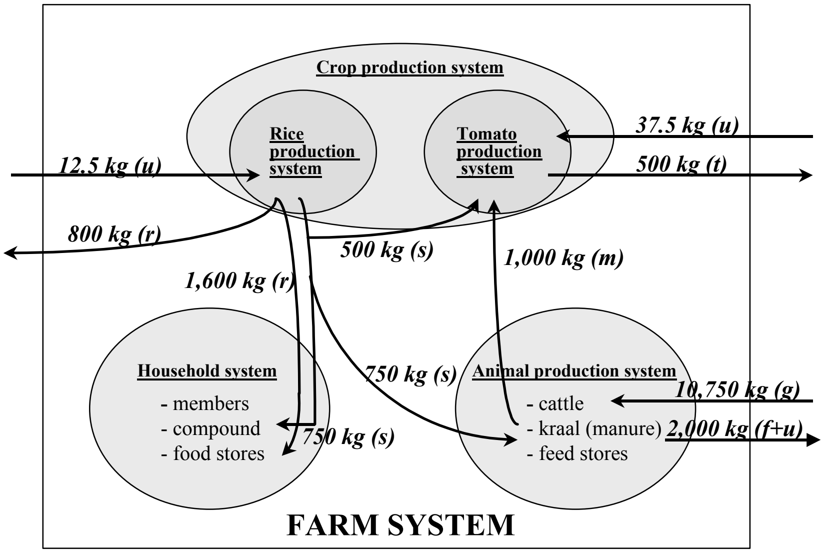
Figure 4.2 Resource flows of the farm system amount of rice straw is stored and used for dry season feeding. The cattle consume crop residues at farm level, and also bring in nutrients from an external source when they feed on common grassland. Our hypothetical farm has very simple nutrient flows as neither its own livestock nor any animals from neighbouring farms graze the fields after harvest.

Quantifying resource flows

The next step towards completing the picture is to estimate the quantities of the flows. First, we need to decide the time scale for measuring flows. Generally a period of 12 months is taken (figure 4.3 shows annual values). However, the cropping season could also be used as the period of measurement, or it could be stretched out over several years.

The quantities involved can be estimated through on-farm observation, discussions with farmers, and actually weighing materials such as crop produce and manure. In principle farmers can do such data collection themselves (see Chapter 6 for more detail), so quantities are often expressed in local units and will need to be converted into kg, using conversion factors.

Our hypothetical farm has an annual rice yield of 3,200 kg/ha. The one field producing rice measures 0.75 ha, so the yearly harvest amounts to 2,400 kg of grain. The farming family sells 800



Rice production system: 0.75ha; tomato production system: 0.25ha
cattle: 5 TLU (Tropical Livestock Units)
u=urea; r=rice; s=straw; t-tomato; m=manure; f+u=faeces and urine; g=grasses

Figure 4.3 Quantified resource flows

kg of rice on the market and consumes the remaining 1,600 kg. The tomato plot measures 0.25 ha, and with an annual production of 2,000 kg/ha, produces a harvest of 500 kg. Each year the farmer uses 500 kg of rice straw as mulch for the tomato plot, and every two years takes 1,500 kg of straw as roofing material for the house (or an average of 750 kg per year). 750 kg of straw is collected and fed to animals in the kraal.

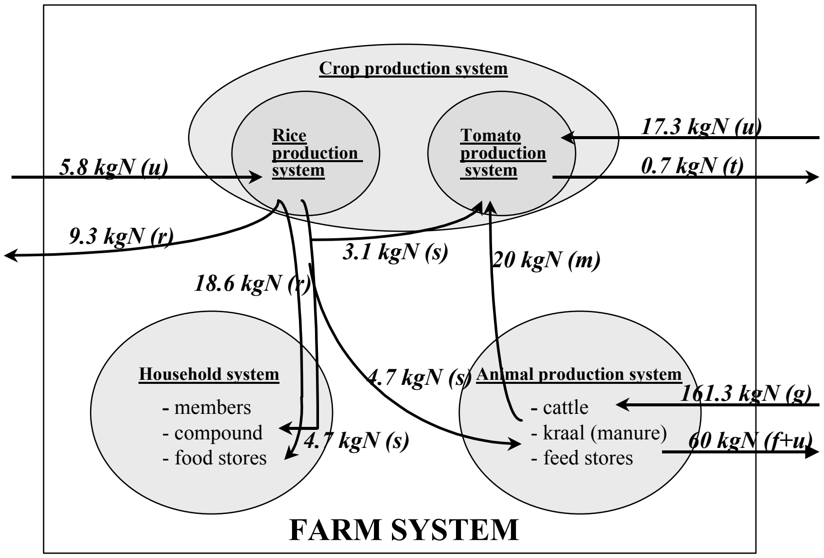
So, on an annual basis a total of 2,000 kg of straw (500 + 750 + 750) leaves the rice field. All the tomatoes are sold on the market. Every year the farmer buys a 50 kg sack of urea, three-quarters of which is used on the tomato plot, and one quarter on the rice plot. The tomato plot receives 1,000 kg of manure in addition to the 500kg of rice straw mulch.

The farmer has a herd of cattle equivalent to 5 Tropical Livestock Units (TLU). As 1 TLU consumes 6.25 kg dry matter per day (see Chapter 3), the 5 TLU on this farm will consume about 11,500 kg dry matter per year. 750 kg of this is straw from the rice fields, which means that the remaining 10,750 kg of dry matter has to come from grazing on communal pastures. On average dry matter fodder is about 55% digestible, so the 5 TLU will annually excrete about 5,000 kg of dry matter faeces. Assuming that the livestock spend 14 hours per day in the kraal, about 3,000 kg of dung will remain in the kraal and 2,000 kg will be left on the grazing land. The urine excreted by the animals constitutes another important source of nutrients.

Quantifying nutrient flows

Having quantified the resource flows we now need to translate them into quantities of nutrients. To keep it simple we have limited this nutrient flow analysis to **nitrogen**, and based the estimates for nitrogen content on the figures in Chapter 3.

The N-content of tomatoes is estimated at 0.13% of their fresh weight. Tomatoes contain 97% of water, and have a very low nitrogen content concentrated in protein in their seeds. Grasses from the communal pastures contain an estimated 1.5% nitrogen. As the N-content of faeces is estimated at 1.5%, the animals leave 2,000 x 0.015 = 30 kg of N on the pastures while grazing there. The N of urine is also about 1.5% (see Chapter 3) and the manure applied to the tomato plot contains about 2% nitrogen.



Rice production system: 0.75ha; tomato production system: 0.25ha
cattle: 5 TLU (Tropical Livestock Units)
u=urea; r=rice; s=straw; t-tomato; m=manure; f+u=faeces and urine; g=grass

Figure 4.4 Nutrient flows quantified

In reality farms often have more fields and more complex interconnecting resource flows than our relatively simple hypothetical farm. Readers wanting to analyse more than one nutrient are advised to use one sheet for each nutrient.

4.2 Calculating partial nutrient balances

We now have the framework to build up partial balances for all the different systems within our farm system:

- the farm system,
- the crop production system,
- the rice production system,
- the tomato production system,
- the household system,

- the animal production system.

To do this we have to 'translate' the flows into input-output functions, as described in Chapter 3.

In each case we have started with the quantified nutrient flows shown in Figure 4.4, highlighting that specific system and flows, and masking out those that are not relevant. Where applicable we have shown the *IN* and *OUT* functions of each flow, based on Tables 3.1 and 3.2 of Chapter 3.

The total values of these balances are calculated for a period of one year.

The N-balance for the farm system

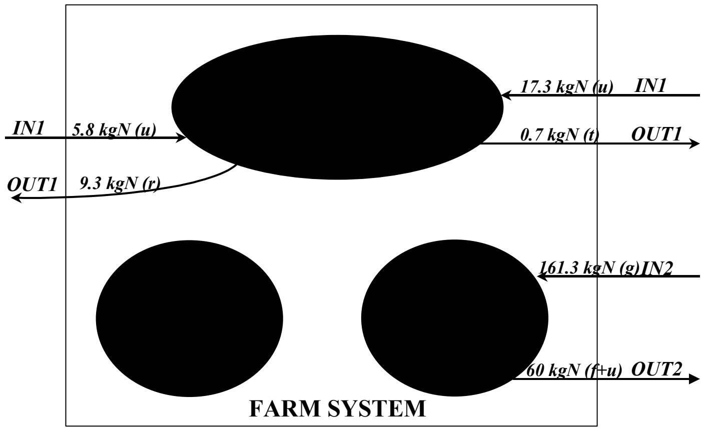


Figure 4.5 Nutrient flows in the farm system

Nitrogen comes into the farm in mineral fertilisers bought at the market (*IN 1*) and through grazing animals on the commons (*IN 2*). *IN2* brings in about 7 times as much nitrogen as *IN 1;* but part of the N input from grazing livestock is excreted in dung and urine and left on the pastures (*OUT 2*). Other nitrogen outflows are the result of selling rice grain and tomatoes at the market (*OUT 1*). A large proportion of the nutrients are stored in the form of animal liveweight

The highly positive balance may suggest that this farm is sustainable (according to these figures the farmer annually adds more than 100 kg of nitrogen to the nutrient stock of his farm). However, to get a picture of what is really happening inside the farm system we need to analyse nutrients in the sub-systems.

Table 4.1 Balance for the farm system

Flow	Resource	Quantity (kg)	N content	N (kg/year)
IN 1	Urea	50	0.46	+ 23
IN 2	Grasses from common pastures	10,750	0.015	+ 161.3
OUT 1	Rice grain	800	0.0116	- 9.4
OUT 1	Tomatoes	500	0.0013	- 0.7
OUT 2	Faeces left on pastures	2,000	0.015	- 30
OUT 2	Urine left on pastures	-	-	- 30
IN-OUT BALANCE				***+ 114.3***

The N-balance for the crop production system

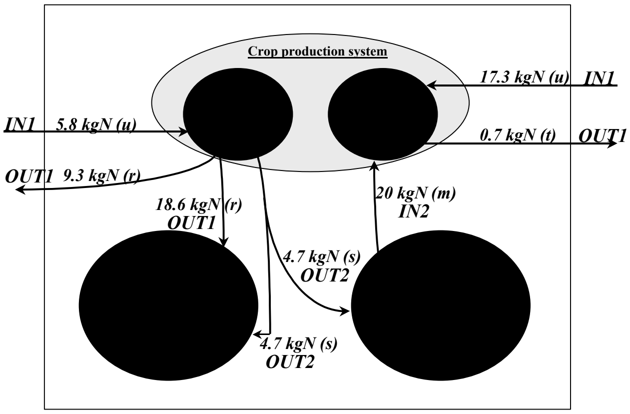


Figure 4.6 Nutrient flows in the crop production system

When we take the crop production system as the unit of analysis a quite different picture emerges. Inputs into the crop production system are urea (*IN 1*) and manure (*IN 2*) produced by the farm's cattle; and the outputs are all crop produce (*OUT 1*) and a large part of the rice straw (*OUT2*), which is used as household roofing material and animal feed. The overall N balance is slightly positive, so we may conclude that the crop production system is sustainable.

Table 4.2 Balance for the crop production system (1 ha of fields)

Flow	Resource	Quantity (kg)	N content		N (kg/year)
IN 1	Urea	50	0.46	+	23
IN 2	Manure	1,000	0.02	+	20
OUT 1	Tomato	500	0.0013	-	0.7
OUT 1	Rice grain	2,400	0.0116	-	27.8
OUT 2	Rice straw	1,500	0.0062	-	9.3
IN-OUT BALANCE				+	***5.2***

The N-balance for the rice production system

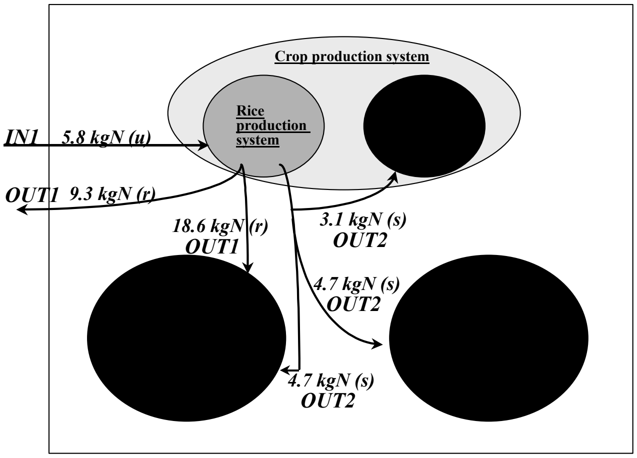


Figure 4.7 Nutrient flows in the rice production system

A closer look at the crop production system shows that the nutrient balance for the rice production system is markedly negative. Urea is the only inflow into the system *(IN 1)*, while substantial amounts of nitrogen are lost when straw is taken (*OUT 2*) for mulch in the tomato plot, for roofing material, and for additional cattle feed *(OUT 2)*. The greatest amount of nitrogen is lost through the removal of rice grain for home consumption and sale *(OUT 1)*.

Table 4.3 Balance for the rice production system (for 0.75 ha rice field)

Flow	**Resource**	**Quantity (kg)**	**N content**	**N (kg/year)**
IN 1	Urea	12.5	0.46	+ 5.8
OUT 1	Rice grain	2,400	0.0116	- 27.8
OUT 2	Rice straw	2,000	0.0062	- 12.4
IN-OUT BALANCE				***- 34.4***

The N-balance for the tomato production system

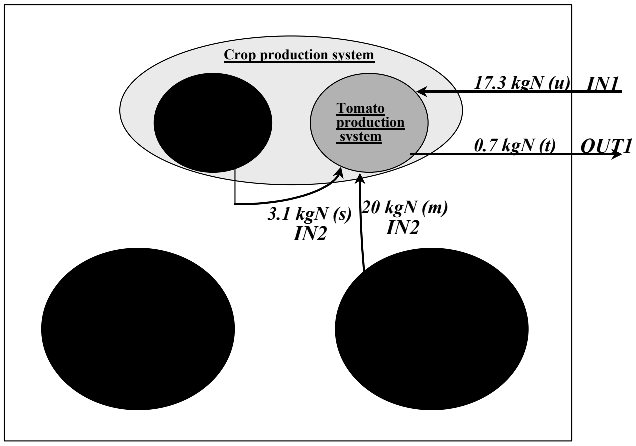


Figure 4.8 Nutrient flows in the tomato production system

The nutrient balance for the tomato production system is quite different to the balance for rice. However, it may be misleading to compare the systems' nutrient flows as these balances have been calculated for different sized fields. For a true comparison the balances should be calculated per hectare.

Most of the urea fertiliser bought by the farmer is put on tomatoes, as they are an important cash crop. Three-quarters of the 50 kg bag is spread on the quarter hectare plot *(IN1)*, as well as manure, which constitutes a relatively large inflow of nitrogen (*IN2*). The system's N output is very small and consists of tomatoes sold on the market (*OUT1*).

Table 4.4 Balance for the tomato production system (for 0.25 ha tomato field)

Flow	Resource	Quantity (kg)	N content	N (kg/year)
IN1	Urea	37.5	0.46	+ 17.3
IN2	Rice straw	500	0.0062	+ 3.1
IN2	Manure	1,000	0.02	+ 20
OUT1	Tomatoes	500	0.0013	- 0.7
IN-OUT BALANCE				***+39.9***

Table 4.4 shows that substantial amounts of nitrogen are accumulating in the tomato plot (at the rate of about 160 kg/ha). However, we know from Chapter 3 that nitrogen is a nutrient that is easily transformed into gas and can also be leached from top soil. The rice straw mulch may well immobilise some of the nitrogen, as decomposing straw with high C/N ratios tends to affect the nitrogen availability in the soil. So despite this apparently high level of N accumulation, even more may be needed to ensure that sufficient N is available to the plants.

The N-balance for the household system

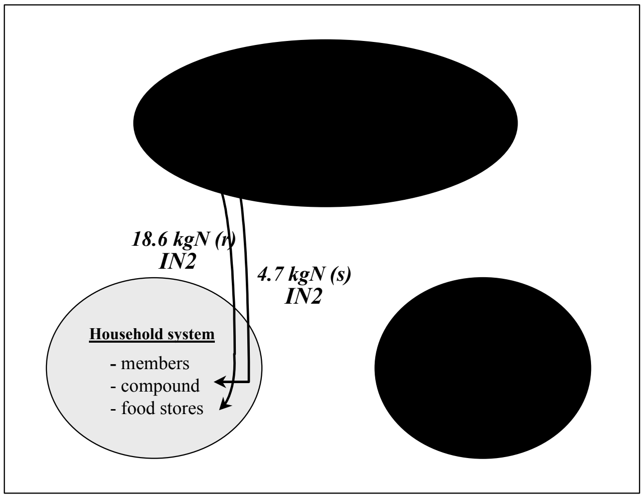


Figure 4.9 Nutrient flows related to the household system

The household system is an important point for storing and transferring nutrients. In Chapter 2 we have shown that nutrients accumulate in and around the settlement. Rice is stored and consumed in the compound and straw is used as roofing material (*IN2*, Figure 4.9*)*. Although no outputs have been identified, insects and other agents such as fungi, rats or bacteria sometimes consume a significant part of the food that is stored. When this decomposes nutrients are freed, just as when humans defecate after eating. As human faeces constitute an important store of nutrients the disposal of such waste is a significant part of nutrient management.[3]

Table 4.5 Balance for the household system

Flow	Resource	Quantity (kg)	N content	N (kg/year)
IN2	Roof straw	750	0.0062	+ 4.7
IN2	Rice grain	1,600	0.0116	+ 18.6
OUT	-	-	-	-
IN-OUT BALANCE				***+ 23.3***

The N-balance for the animal production system

Animals grazing on common pastures ingest a significant quantity of nitrogen (*IN2*), some of which is used for production (milk, meat) and reproduction (calves), and some of which is excreted (faeces and urine: *OUT2*). Every year the cows in our hypothetical farm leave about 60kg of nitrogen in the faeces and urine they deposit on common pastures, and about 90kg of nitrogen in the faeces and urine they deposit in the kraal (3,000 x 0.015 = 45 kg N from faeces and an equal amount from urine). As only 20 kg of nitrogen is taken out of the kraal to manure the tomato fields (*OUT2*), the kraal represents an important nitrogen sink.

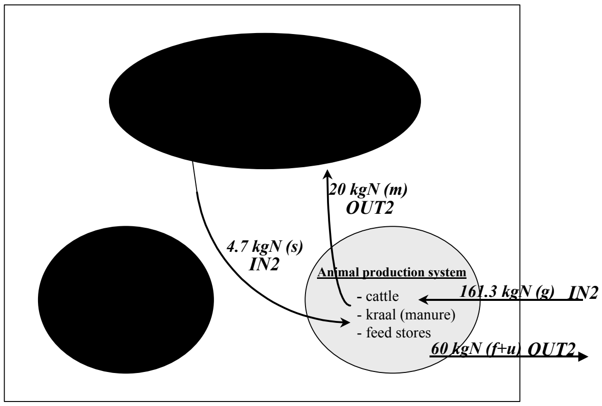


Figure 4.10 Nutrient flows in the animal production system

Table 4.6 Balance for the animal production system

Flow	Resource	Quantity (kg)	N content	N (kg/year)
IN 2	Rice straw	750	0.0062	+ 4.7
IN 2	Grasses from common pastures	10,750	0.015	+ 161.3
OUT 2	Faeces left on pastures	2,000	0.015	- 30
OUT 2	Urine left on pastures	-	-	- 30
OUT 2	Manure to fields	1,000	0.02	- 20
IN-OUT BALANCE				***+ 86.0***

Assessing and comparing these balances will reveal the present state of the farm and may suggest ways to improve nutrient management:

(i) Animals are very important for the farm system as a whole because they harvest many nutrients whilst grazing on common pastures;

(ii) The crop production system as a whole seems sustainable in terms of its nitrogen balance. Nitrogen is accumulating in the tomato production system, but the rice production system has a severe negative N balance and may be in danger if this nitrogen mining continues.

The N-balances can be redressed by increasing mineral and organic inputs (*IN 1* and *IN 2*) and/or decreasing outputs (e.g. reducing the amount of straw removed, *OUT 2*).

(iii) The household and animal production systems are accumulating nitrogen, and could be used as a source of nutrients to correct the negative balance in the rice production system. The kraal is rich in nitrogen, and improvements in the storage and handling of manure could increase the amount and quality available for use on the rice fields.

4.3 Nutrient balances and stocks: the long-term perspective

A single negative nutrient balance does not tell us much about the future of the system unless we also know what is available in the general stock of nutrients. When considering the **crop production system and its sub-systems** we need to be able to gauge whether nutrient mining is actually threatening the stock of nutrients in the soil, as a negative balance is obviously much more serious when overall nutrient stocks are low. The long-term perspective(s) of a crop production system cannot be assessed solely on the basis of partial nutrient balances. The ***nutrient stock:balance (NSB) ratio*** may be a better indicator of sustainability, giving a more accurate indication of how long farming can continue in the same way, given the available nutrients.

Let us compare two crop production systems.

(1) has a negative balance of 75 kg N/ha/year

(2) has a negative balance of 100 kg N/ha/year.

At first sight the second system seems most at risk. However, if we know that (1) has available nitrogen reserves of 850 kg/ha, and (2) has available nitrogen reserves of 1,600 kg/ha, a different picture emerges. The first system has an NSB ratio of about 11, while the NSB ratio for the second is 16, which implies that the second system could sustain production longer than the first.

However, the NSB ratio is only a rough guide, since we have not considered every nutrient flow, and the data for the flows in question is based on farmers' estimates of quantities of produce and average nutrient contents.

This example shows that the real significance of a negative nutrient balance can only be assessed in relation to the available nutrient stock. It is therefore important to carry out a soil analysis to determine the stocks of nutrients actually available in the soil. For nitrogen we take the **'dynamic N-**

reserve', for phosphorus the **'P-Bray'** represents the immediately available stock, and **'K-exchangeable'** is used for potassium (see Chapter 3).

Another shortcoming of the NSB ratio as an indicator of a crop production system's sustainability is the fact that in practice it is impossible to deplete all the soil's nutrient reserves. The system will clearly become non-productive well before all the dynamic nutrient reserves are consumed. When determining the NSB ratio we should therefore not take the whole nutrient stock into account, but only that part which is greater than the 'minimum level' of soil nutrient reserves required for sustaining production. Although it is difficult to make general statements about these minimum levels of soil nutrients, in practice one should avoid going below the 'very low levels' shown in Tables 3.4, 3.5 and 3.6 (see Chapter 3).[4] This means that the bench mark for assessing the potential life of a crop production system is the 'very low level of nutrient availability', and only figures above this should be used to calculate the NSB ratio.

The rice production system analysed in section 4.2 has a 0.75 ha rice field with a negative balance of 34 kg N per year, representing an estimated nitrogen loss of 45 kg/ha/year. Assuming that the soil has a 'dynamic N-reserve' of 1,000 kg/ha, it will take 6 years of rice mono-cropping before this reserve drops below the 'very low' level of 750 kg/ha. However, if the dynamic N-reserve is 2,000 kg/ha, the field can sustain nitrogen losses of 45 kg/ha/year for 27 years before the level drops below 750 kg/ha.

(It should be noted that these calculations only give a rough estimate of how long depletion can continue).

4.4 Nutrient flow analysis in practice

Once all the relevant data needed to quantify flows and estimate their nutrient content are available it is relatively straightforward to analyse them and calculate partial nutrient balances. It is not so easy to obtain reliable source of data, neither to decide where to get the data from and what is essential. Given the difficulties of acquiring reliable data, nutrient flow analysis is often more demanding than it first seems, and should therefore only be used when there are strong reasons to do so.

In farming systems where grain yields are low (less than 200 kg/ha) and crop residues are not systematically removed from the field there is little justification to go through such an exercise.

Nutrient flows are limited, and yield levels can probably be maintained without using additional fertilisers. However, where there have been relatively **significant changes** in the pattern of nutrient flows it can be very helpful to analyse them.

A case in point is North Sukumaland, where the natural reserves of *Hyparrhenia* grass, the traditional roofing material for houses, are becoming exhausted. The use of rice straw has consequently increased considerably, so that more nutrients now leave the field in straw than in harvested grain. It would be useful to work with farmers here on nutrient flow analysis to identify measures that would ensure more sustainable use of the land.

Another situation where nutrient flow analysis would be useful is when there are **obvious imbalances** in the way fertility is used. Manure may be left unused because there is no adequate transport, or because of taboos (which particularly affect the use of human waste). If there are no alternative sources such as imported mineral fertilisers, farmers in these situations must choose between using the available manure or accepting a steady decline in their soil's fertility.

Once the decision has been made to analyse nutrient flows, the next issue is the collection and selection of data. There are an almost infinite number of flows in a village or even a farm, and measuring them all would be an endless, costly and time-consuming process. Anyone considering flow analysis should be very clear about what they are going to use it for, and adapt it to that particular purpose and context, whether it is as a learning tool in work with farmers or as part of a scientific research project investigating the causes of declining soil fertility. It should be noted here that different criteria should be used to evaluate the outcomes of scientific research and analysis done with farmers.[5]

In this chapter we looked at how farmers and field practitioners can use nutrient flows as part of a learning process, using knowledge gained from earlier exercises to carry out the analysis. It is the farmers and field practitioners who develop the materials for this analysis, drawing resource flow maps (see Chapter 6) and deciding on the units of quantification. If farmers quantify manure application on their fields in terms of the number of donkey-drawn carts per hectare, then the average cartload is the unit of quantification; and the same holds for bundles of straw used as bedding in kraals or as roofing material, for the rolls of cowpea vine used as animal feed, and for flattened cakes of dried manure sold as fuel.

Outsiders must study a language before they can use it to communicate, and scientists and extension staff who want to stimulate and participate in farmers' resource flow analysis **must not try to replace the local set of standards and units** with internationally accepted units of weight and content. The world is still full of people that routinely use *bags* (East and Southern Africa), *baskets* (Burma), *bales* (India), *acres* and *gallons* as references to indicate weight, field size and volume; and it is these familiar measurements that should be used as the tools of analysis.

So far we have looked at investigating resource flows for a **single farm**. However, this methodology can also be used to analyse farm systems that typically belong to different **social groups**. Chapter 6 outlines how to use diversity analysis to define these social groups, using criteria such as the amount of land owned, the quality of the land-holding, cattle ownership, and the availability of labour and transport, farm equipment, etc.[6]

Nutrient flow analysis can also be used on a more general level, to inform **policy making** decisions and **priorities for research and extension work**. It can show which parts of the farming system are unsustainable and whether certain social groups face particular problems in maintaining soil fertility, as well as indicating how to improve management and distribution and the best use of new and existing sources of fertility.

Notes to Chapter Four

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[1] Increasingly, African farmers are producing for global markets; not only traditional cash crops, like cotton in Mali, but also string bean and flower growers in Kenya and Tanzania that now supply markets in Western Europe. This trend is likely to intensify in the future.

[2] The Nutrient Monitoring (NUTMON) project has done extensive work on drawing up nutrient balances at the farm household level. These balances take account of all the input and output functions determined by Smaling, and are made on the basis of monthly surveys of a large number of farmers. Apart from nutrient balances, the NUTMON project has also been instrumental in developing methodology for drawing up economic balances at farmers' level. More details can be found in the special issue of Agriculture, Economics and Environment, Vol. 71 (**Smaling EMA**, Ed; 1998), which is a collection of major relevant works on nutrient balance; and **Pol F** (1992), who uses secondary data and data from (inter)national data bases to calculate balances at the regional or sub-regional level. Pol is presently collaborating with FAO on the development of guidelines for calculating and valuing nutrient fluxes and balances.

[3] Disposal strategies of human faeces and urine are important to consider. It makes a difference when defecation takes place in deep pit latrines or back into the field. Remember the description in Chapter 2 on how the forest belt surrounding Adja villages got enriched, and later became an important productive part of the system. In traditional banana production in the West Lake area in Northwest Tanzania, defecation took place at the foot of the banana plants. Promotion of deep pit latrine construction, as part of a health improvement program, had serious consequences for the nutrient flows of this system. Deep pit latrines work negatively in the sense that nutrients are concentrated at the bottom of the pit instead of spread, and generally can no longer be reached by plant roots. Disposal strategies of human faeces and urine are important to consider. If there is any doubt about the importance of human manure in maintaining livelihood systems you are invited to read **Wen Dazhong, Pimentel D** (1986), for reference about old China. While disposal and eventual use of human manure may be culturally taboo as a subject for discussion, in nutrient-poor environments, and in the absence of possibilities to use imported nutrients, students of livelihood system sustainability are advised not to ignore this important factor. A family of 4 adult persons produces waste that contains an estimated 21 kg nitrogen yearly. Compare this to a 50 kg sack of urea where we find 23 kg of nitrogen. Using human waste would not only save the costs of one sack of urea; waste contains many more nutrients that are needed for crop production, that are not supplied by the mono-nutrient fertilizer urea. Another way to compare the importance of the yearly deposition of nitrogen in the form of human faeces is found in Stoorvogel and Smaling's Africa-wide study on nutrient depletion on agricultural land. The authors estimate the current yearly loss per hectare at 22 kg of nitrogen. So, the nitrogen found in human faeces of an average family is roughly equal to the nitrogen deficit of one hectare of cropped land. **Stoorvogel JJ, Smaling EMA** (1990).

[4] To make such statements one would need to know site and crop specific relationships between nutrient depletion and yield. Such relationships would not only be site and crop specific, but would probably also depend on how the nutrient depletion has come to pass: through plant uptake, erosion, leaching, acidification, changes in soil biology, etc.; Note from **Brouwer J** (1998).

[5] This is not meant as an easy excuse for analytical results that are scientifically unsatisfactory. The point here is that this guide's primary objective is to help farmers learn, not to satisfy scientific research. There is no room for scientists to challenge the results of the analysis, only for creative contributions that may improve the framework, given the context and limitations of its use.

[6] For more details see **Defoer T, De Groote H, Hilhorst T, Kanté S, Budelman A** (1998).