

## Maintaining soil quality

To get a good yield, rice plants should be in good health. As the soil is the primary source of plant nutrients, the soil should also be in good health, i.e. it is important to maintain or improve soil quality. As we saw in Module 7, the soil has to be well prepared, but it is also important to ensure that the soil can provide all the nutrients the rice plants need (References 14 and 15).

*Note: to simplify calculations of fertilizer needs in this module, all figures related to phosphorus (P) are expressed in reality in units of  $P_2O_5$ , and all figures related to potassium (K) are expressed in reality in units of  $K_2O$ .*



### Learning objectives

At the end of this module farmers will:

- Have exchanged their knowledge on what a good soil is.
- Have gained basic knowledge about plant nutrients:
  - The relative importance of the different nutrients;
  - Rice nutrient demand;
  - Nutrient uptake from the soil;
  - Nutrient inputs from organic amendments and mineral fertilizer.
- Be aware of nutrient fluxes in the soil.
- Be able to assess rice nutrient demand and corresponding fertilizer needs.
- Be able to recognize the importance of organic amendments.
- Decide on experiments aimed at improved soil-fertility management.

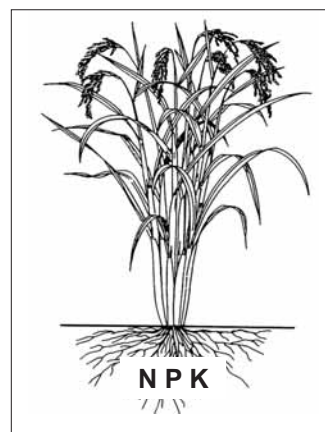
- ❶ Appreciate farmers' perceptions on the concept of 'soil quality.'
- ❷ Introduce basic ideas of plant nutrients.
- ❸ Discuss the different types of mineral fertilizers and organic amendments.
- ❹ Introduce fertilizer solubility.
- ❺ Introduce fertilizer leaching.
- ❻ Introduce the notions of potential yield, attainable yield, target yield and yield gaps.
- ❼ Introduce the notion of nutrient-omission plots to estimate the soil's capacity to supply nitrogen (N), phosphorus (P) and potassium (K).
- ❽ Estimate fertilizer needs to reach a target yield taking into account the soil's nutrient-supplying capacity.
- ❾ Introduce experiments that focus on improving soil-fertility management.

## Module 10

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#### Procedure

1. Farmers and the PLAR-IRM team meet at the PLAR-IRM Center. The facilitator briefly reviews the previous module and invites farmers' feedback.
2. One of the PLAR-IRM team members explains the learning objectives and procedures for the current module.
3. Discussions of farmers' perceptions of a good-quality soil capable of producing plants in good health. The facilitator introduces the discussion by addressing the following items:
  - What is a good-quality soil?
  - What does a plant need to develop well and protect itself against diseases?
  - What are the characteristics of a soil with a good nutrient-supplying capacity?
  - What do plants 'eat'?
  - How do they 'eat'?
  - What is the role of the roots and what is the relationship between root development, nutrient uptake of plants and rice development?
4. The facilitator introduces basic notions about plant nutrition:
  - Organic matter and mineral elements.
  - Decomposition of organic matter.
  - Nutrients in the soil solution.
  - The major nutrients for crop production: N, P and K.
  - Specific roles of these nutrients (N, P and K) in plant growth and development.
  - Soil nutrient reserves.
  - External nutrient inputs: organic and mineral fertilizers.
5. Discussion of the different types of mineral fertilizers.
  - Types of mineral fertilizers the farmers know, those available and those they use.
  - Single-component fertilizers and compound fertilizers, their nutrient composition; dosage of the nutrients; meaning of '%' and the real quantity of nutrients in fertilizer bags:



Single-component fertilizer: there is only one nutrient in this type of fertilizer:

- e.g. urea: contains only nitrogen,
- e.g. TSP (triple super phosphate): contains only phosphorus;

Compound fertilizers: there are several nutrients in this type of fertilizer:

- e.g. NPK: contains nitrogen, phosphorus and potassium;

The nutrient content is usually expressed in percentage of N, P and K on the fertilizer bag:

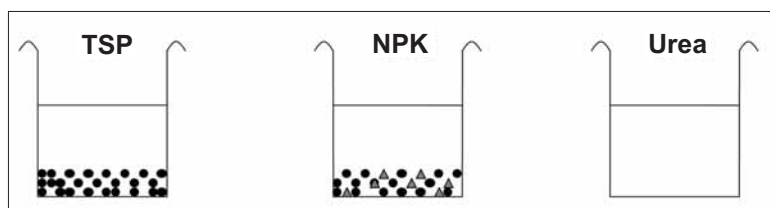
- urea: ‘46% N’ means that for every 100 kg of urea, there is 46 kg of nitrogen, the rest of the fertilizer is inert material,
- NPK is often 10-20-20 in Côte d’Ivoire (10% N, 20% P and 20% K)<sup>1</sup>, which means that 100 kg of NPK contains 10 kg of nitrogen, 20 kg of phosphorus and 20 kg of potassium,
- TSP: ‘45% P’ means that 100 kg of TSP contains 45 kg of phosphorus;

The quantities of nutrients in fertilizer bags:

- Urea: 100 kg of urea contains 46 kg of nitrogen, so a bag of 50 kg contains 23 kg of nitrogen,
- NPK: 100 kg NPK (10-20-20) contains 10 kg of nitrogen, 20 kg of phosphorus and 20 kg of potassium; so a bag of 50 kg NPK contains 5 kg of nitrogen, 10 kg of phosphorus and 10 kg of potassium.

#### 6. Solubility of fertilizer.

- The facilitator demonstrates the solubility of different mineral fertilizers. She/he takes an equal quantity (e.g. 100 g) of three different types of fertilizers—urea, NPK (10-20-20) and TSP—and puts each in a different container. The same amount of water is added (e.g. 500 ml) and each container’s contents are mixed. After five minutes, the farmers have a look and determine the level of solubility of the three types of fertilizer.



- The facilitator introduces some notions of the consequences of solubility: absorption (uptake), mobility of nutrients and risks of losses due to leaching, i.e. the downward movement of water beyond the reach of the root zone.

#### 7. Leaching of nutrients.

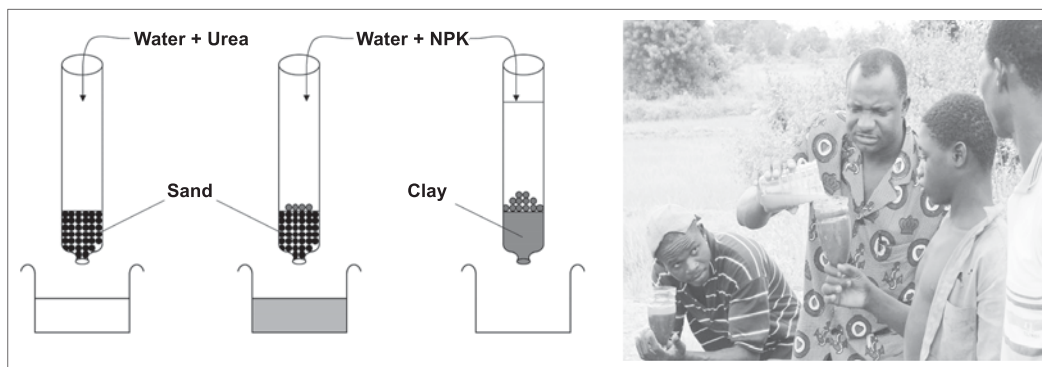
- The facilitator demonstrates that nutrient leaching depends on the type of soil. She/he takes three empty water bottles from which the bottom has been removed and fills these with three different kinds of soil: two with sandy soil and one with clay soil. She/he then adds

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water with dissolved urea to the first bottle filled with sand, and water with NPK to the second bottle (filled with sand) and the third bottle (filled with clay). Farmers observe the percolation of the solution in each of the three bottles (wait about 15 minutes).



- The facilitator talks about the necessity of dividing up urea inputs according to when the plant needs nitrogen most, i.e. at the start of tillering and at panicle initiation. This is particularly important for sandy soils. Phosphorus and K are usually applied as basal fertilizers, i.e. before or at transplanting or sowing.
  - Next, the facilitator facilitates a discussion on the possibility of diminishing the effects of leaching by incorporating organic resources in the soil, e.g. decomposed rice straw.
8. The facilitator introduces the concept of potential yield and compares this with a ‘yield ceiling’—the maximum yield that can be obtained with optimal integrated rice management (without pest and disease problems, nutrient deficiencies, etc.). She/he explains that, with good water management, this yield ceiling is only determined by climate (temperature and solar radiation). For undeveloped inland-valley lowlands without good water control, the yield potential is also a function of water availability during the season. The facilitator stimulates a discussion on the yield potential in farmers’ fields. Are there any differences in terms of yield potential within the inland valley? Are there differences in terms of yield potential if a short- or medium-duration rice cultivar is used? For inland valleys where two crops of rice can be grown per year, it is important to talk about differences in yield potential between the growing seasons.
  9. The facilitator introduces the notion of obtainable yield. She/he explains that it is not realistic to aim at attaining the potential yield. The obtainable yield is about 70 to 80% of the potential yield.
  10. The facilitator introduces the concept of actual and target yields. She/he explains that farmers should go for a realistic target yield, that aims at obtaining a yield gain of between 0.5 and 1 t/ha compared to actual yield. With an example, she/he shows the three types of yield gap that exist (Reference 15): the yield gap between actual yield of a farmer and the yield obtained

by the best farmer (Yield gap 1); the yield gap between best farmer yield and attainable yield (Yield gap 2), and the yield gap between attainable yield and potential yield (Yield gap 3).

11. The facilitator introduces the concept of small (5 m × 5 m) nutrient-omission plots: zero-N, zero-P and zero-K mini-plots. Yields obtained on such plots can be used as a proxy for the capacity of the soil to supply nitrogen, phosphorus and potassium, respectively. Nutrient-omission plots should be installed at representative sites, where farmers expect to see a differences in terms of soil fertility (e.g. nutrient-omission plots should be installed on the major soil types, on sites that have been cultivated for a long time, and on sites that have been under fallow for a number of years).
12. The facilitator presents rice N, P and K needs to obtain a 1 t/ha increase in rice yield, while maintaining balanced nutrition: 15 kg of nitrogen, 6 kg of phosphorus and 18 kg of potassium (Reference 15).<sup>2</sup>
13. The facilitator discusses how to calculate fertilizer-nutrient needs, based on yields obtained in the zero-N, zero-P and zero-K plots, a target yield and balanced nutrition of 15 kg N, 6 kg P and 18 kg K to obtain a yield gain of 1 t/ha. The facilitator uses a recovery percentage of 30% for nitrogen and potassium and 20% for phosphorus. She/he can take the example used in Reference 15, but it is better to use data obtained from the field or to ask farmers to give estimations of yields obtained in the zero-N, zero-P and zero-K plots. Careful: the target yield should not be higher than attainable yield (i.e. 70 to 80% of potential yield) as nutrient needs to obtain a 1 t/ha yield gain increase rapidly above attainable yield.
14. The facilitator leads a debate on recovery rates used to calculate fertilizer needs. She/he makes a distinction between nitrogen, an nutrient that is very mobile, and potassium and phosphorus that are less mobile. She/he explains that there are often positive residual effects of P and K application in subsequent years. However, for nitrogen, losses are irreversible. She/he explains that it is, therefore, very important to try to increase the nitrogen recovery rate. She/he leads a debate on the importance of applying nitrogen fertilizer in several splits and on the importance of good crop management in general (Reference 15, Box 4).
15. The facilitator leads a debate on the nutrients that are exported from the farmer's field after harvest. She/he presents first the percentage of nitrogen, phosphorus and potassium in the rice plant at maturity in case of balanced nutrition (Reference 15):

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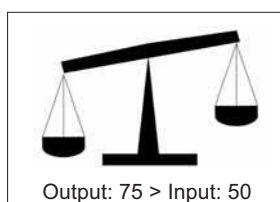
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*Nitrogen, phosphorus and potassium concentrations in rice grain and straw (%) in case of balanced nutrition*

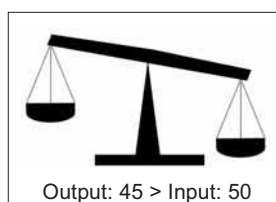
	Nitrogen	Phosphorus	Potassium
Grain	1.0	0.4	0.3
Straw	0.5	0.2	1.5
Total	1.5	0.6	1.8

- The facilitator first discusses nutrient exportation from the field. She/he explains that with rice harvest, the grain and a large portion of the straw produced are exported from the field, and with it a significant quantity of nutrients:
  - Laboratory analyses have shown that for a harvest of 5000 kg of paddy rice per hectare, about 50 kg of nitrogen, 30 kg of phosphorus and 15 kg of potassium are removed from the field with the grain harvest;
  - At the same time, a large fraction of the straw is removed as well. If all straw is removed, about 5000 kg of straw is produced, and this means that an additional 25 kg of nitrogen, 15 kg of phosphorus and 75 kg of potassium are removed from the field; this shows that rice straw contains a lot of potassium;
  - The total amounts of nutrients exported from a rice field with a yield of 5 t paddy/ha and 5 t straw/ha is, therefore, 75 kg of nitrogen, 45 kg of phosphorus and 90 kg of potassium.
- Next, it is possible to compare what is exported from the field with the harvest, and what has been brought in with fertilizers (for example, let us say 50 kg N/ha and 50 kg P/ha). We now can make a nutrient balance:

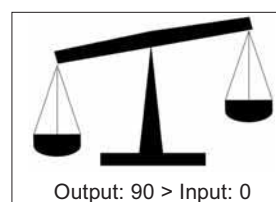
*for nitrogen*



*for phosphorus*



*for potassium*



Balance: –25 kg of nitrogen/ha: the soil N reserves decrease.

Balance: +5 kg of phosphorus/ha: the soil P reserves increase.

Balance: –90 kg of potassium/ha: the soil K reserves decrease.

- The facilitator stimulates a debate on the danger of ‘mining’ the soil’s nutrient reserves. Often, zero-K plots will indicate that there is no need to apply potassium. In the long run, and if high yields are obtained and straw is removed from the field, this may not be sustainable and K-deficiency symptoms may start to appear. A maintenance application may, therefore, be needed to avoid mining of the soil’s K reserves. Using organic amendments, such as compost, rice straw or manure, helps maintain soil fertility and the soil’s nutrient reserves. The combined use of organic resources and mineral fertilizers increases the capacity of the soil to supply nutrients and may also increase the recovery rate of mineral fertilizer nutrients.
16. The facilitator leads a discussion on the possibility of running an experiment on fertilization (Reference 17).<sup>3</sup>
- The farmers talk about the types of fertilizer they use, in what quantities per unit area, and the number of split applications per growing season.
  - The facilitator asks the farmers if they know and follow the recommendations (from the extension service) concerning the mineral fertilizer doses to apply:
  - In Côte d’Ivoire, the official recommendation for rice, over the whole country, is 200 kg NPK and 100 kg urea per ha.
  - The farmers discuss the recommended doses of N, P and K according to the extension service.
  - The facilitator introduces the idea of testing alternative doses, closer to the real nutrient requirements. To do this, it is necessary to know more about the soil fertility of the inland valley.<sup>4</sup>
  - With the facilitator, the farmers decide which alternative doses they want to test (treatments) in comparison with their own fertilizer practices and the recommended doses. The names of volunteer farmers are listed.
  - The farmers agree on the dimensions of the trial plots of the experimental design.
  - The field work will be done in Module 12.
17. Evaluation: the facilitator asks what the farmers appreciated (or did not appreciate), what they learnt, and what they intend to do with their newly obtained knowledge.
18. The facilitator concludes the session and invites the farmers to the next session.

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3. This concerns farmers that have volunteered to do this type of experiment, it may be useful to have a special meeting with only these farmers.

4. If this is not the case, it is better to start with nutrient-omission trials to get an idea of the variability in terms of soil fertility in the inland-valley lowlands. The mini-plots need to be installed at representative sites where the farmers expect differences in terms of soil fertility (e.g. on the main soil types, on fields that have been cultivated for a long time, or have just been brought under cultivation). The following season these results can be used to test alternative soil-fertility management options.

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#### Time required

- Three hours



#### Materials required

- Six empty mineral-water bottles:
  - 3 without bottoms, filled with soil: two with sandy soil and one with clay soil;
  - 3 with cut tops, serving as holders for the 3 filled with soil samples.
- 100 g of different fertilizers: NPK, urea, TSP, etc.
- A container for water.
- Strong packing paper, markers.

#### *Box 10*

The farmers in Bamoro decided to compare the dose recommended by the extension service (200 kg 10-20-20 and 100 kg of urea/ha) with several alternative doses.

- The farmers became aware that the recommended dose contains relatively little N, but a lot of P and K (i.e. 66 kg N, 40 kg P and 40 kg K).
- As a first alternative they wanted to invert the NPK and urea dosage: 100 kg of 10-20-20 and 200 kg of urea per hectare; that is 102 kg N, 20 kg P and 20 kg K per hectare, thus a higher dose of N (considering the potential losses of this nutrient that is easily leached), and less P and K.
- The farmers also wanted to test if P and K application is really necessary; so another alternative was proposed: applying only urea at 200 kg/ha.