A new praxeology for integrated nutrient management, facilitating innovation with and by farmers

M. Deugd, N. Röling, E.M.A. Smaling

Abstract

Integrated nutrient management (INM) is a broad-based remedy against excessive soil fertility decline or accumulation, problems which are increasingly recognised as major constraints to farming in both temperate and tropical hemispheres. The different technical indicators of INM (nutrient stocks, nutrient flows, technologies) are listed in the paper. At the same time, INM requires social interventions to arrive at technologies that simultaneously improve soil fertility in a sustainable way, and make sense to farmers given their different social and economic motives. As the limitations of transfer of technology to promote better INM become more obvious (particularly in lesser-endowed regions in the tropics), there is a need to develop new strategies, focussing on the facilitation of farmer learning to become experts at INM and at capturing the opportunities in their diverse environments. Facilitating INM therefore, requires a praxeology (theory informing practice, and practices feeding new theory) about facilitating innovation, focussing on enhancing the farmers’ capacity to observe, experiment, discuss, evaluate and plan ahead. The paper lists the work needed to facilitate this learning with respect to INM, borrowing a leaf from earlier successes in the field of integrated pest management (IPM). Indispensable ingredients are participatory rural appraisals and participatory technology development, which emphasizes mutual open-mindedness and empathy between all the participants. The paper provides guidelines for the development of INM learning, but further field testing still has to be undertaken.

Keywords: Extension science; Farming systems; Farmer field schools; Integrated nutrient management; Praxeology

1. Introduction

Soil fertility management is one of the issues of importance to farmers throughout the world. Farmers pay different degrees of attention to it, and follow different approaches to meet the targets they have set for themselves. Some reach these targets, others do not. There are roughly three groups of farmers: (1) those who enhance fertility in order to reach high agricultural output, often causing high emissions to the environment, (2) those who manage to more or less maintain the same soil fertility level (traditional shifting cultivation and ecological farmers), and (3) those who do not manage to maintain soil fertility (farmers that have no interest or no means to invest in soil fertility). Soil fertility management is an integral part
of farm management with its particular spatial and
temporal characteristics. This is why the authors think
the term ‘integrated nutrient management’ (INM)
more appropriately hints at the different options at
hand to achieve certain soil fertility goals. This paper
deliberately defines INM as the ‘judicious’ manipula-
tion of nutrient stocks and flows, in order to arrive at a
‘satisfactory’ and ‘sustainable’ level of agricultural
production. The authors consider that there are basic-
tlly two ways to look into INM, i.e., through the hard
science approach, attempting to quantify or estimate
what is meant by judicious, satisfactory and sustain-
able, or through participatory approaches, leaving
room for different views, perceptions and realities
(Engel and Salomon, 1997). The first approach uses
and generates fundamental, scientific knowledge on
nutrient flows (Table 1) and INM technologies
(Table 2), whereas the latter uses a combination of
scientific, experiential and religious–cultural knowl-
edge, and is tailored to a particular agro-ecological
and socio-economic situation. Building bridges
between the fundamental, linear approaches and the
broader, discontinuous, transcultural ones constitutes
a major challenge to (social) scientists, and calls for a
‘praxeology’: a theory informing practice, which in
turn feeds theory, i.e., a self-regulating interplay
between fundamental and applied science (Nas et al., 1987; Nas, 1997). The praxeological battlefield
is pluriform in that it includes theoretical aspects
(systematic comparison of sectors through cases),
action aspects (intervention for innovation), and meth-
odological aspects (using scientific results in the real-
world development practice). This pluriformity can
also be expressed in terms of ‘desirability’ (building
society according to a certain ideology), ‘autonomy’
(fundamental science is not steered by societal con-
siderations) and ‘feasibility’ (social intervention).
Social intervention is the tool for the joint develop-
ment of INM technologies. Praxeology draws atten-
tion to the fact that development practice, including

Table 1
Nutrient inputs and outputs and internal flows at farm level (Smaling and Braun, 1996)

<table>
<thead>
<tr>
<th>Nutrient inputs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN1</td>
<td>Mineral fertilizers</td>
</tr>
<tr>
<td>IN2</td>
<td>Organic inputs</td>
</tr>
<tr>
<td>IN2a</td>
<td>Concentrates for livestock and fish</td>
</tr>
<tr>
<td>IN2b</td>
<td>Other organic feeds for livestock and fish</td>
</tr>
<tr>
<td>IN2c</td>
<td>Urban and agro-industrial waste</td>
</tr>
<tr>
<td>IN2d</td>
<td>Manure obtained from outside the farm</td>
</tr>
<tr>
<td>IN2e</td>
<td>Manure from farm livestock grazing outside the farm during part of the day</td>
</tr>
<tr>
<td>IN2f</td>
<td>Food for the farm obtained from outside the farm</td>
</tr>
<tr>
<td>IN3</td>
<td>Atmospheric deposition in rain and dust</td>
</tr>
<tr>
<td>IN4</td>
<td>Biological nitrogen fixation</td>
</tr>
<tr>
<td>IN5</td>
<td>Sedimentation</td>
</tr>
<tr>
<td>IN6</td>
<td>Sub-soil exploitation by trees and other perennial crops</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nutrient outputs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUT1</td>
<td>Harvest crops, meat, milk and fish leaving the farm</td>
</tr>
<tr>
<td>OUT2</td>
<td>Crop residues and manure leaving the farm</td>
</tr>
<tr>
<td>OUT3</td>
<td>Leaching below the root zone</td>
</tr>
<tr>
<td>OUT4</td>
<td>Gaseous losses (including denitrification, ammonia volatilisation, and burning)</td>
</tr>
<tr>
<td>OUT5</td>
<td>Runoff and erosion</td>
</tr>
<tr>
<td>OUT6</td>
<td>Human faeces ending up in deep pit latrines</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Internal flows</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL1</td>
<td>Crop residues fed to tethered farm animals or applied to certain plots</td>
</tr>
<tr>
<td>FL2</td>
<td>Biomass from plots under pasture and fallow eaten by animals</td>
</tr>
<tr>
<td>FL3</td>
<td>Animal manure from within the farm applied to certain plots</td>
</tr>
<tr>
<td>FL4</td>
<td>Crops, milk, meat and fish, obtained from the farm eaten by the farm family</td>
</tr>
<tr>
<td>FL5</td>
<td>Food remnants and farmyard manure applied to certain plots</td>
</tr>
</tbody>
</table>
investment decisions, human resource development curricula, donor strategies, project design and, significantly as shall be shown, strategies to facilitate innovation, is informed by theory about likely outcomes of activities. J.M. Keynes once observed that the people who claim to be practical and are not in need of theory usually turn out to be operating on the ‘theories of yesteryear’. A theatre of practice such as the facilitation of innovation, marked as it is by uncertainty and failure, is in need of continued reflec-
tion and rethinking of the grounds for action. In other words, it is in need of deliberate praxeology development, of continuous scrutiny of the theories that inform it.

This article aims to provide a praxeology for the area of INM (Smaling and Braun, 1996; Smaling et al., 1996), while borrowing a leaf from the past research in the field of integrated pest management (IPM; Röling and Van de Fliert, 1994; Röling and Van de Fliert, 1998). IPM emerged in response to the second generation problems of crop protection through exclusive reliance on chemical pesticides (Kenmore, 1980). As to INM, similar problems have been recognised with respect to the use of mineral fertilisers (IN 1 in Table 1) as a technical fix of soil fertility problems. Yet soil nutrient deficiencies are increasingly looming large as a key development problem in many places in the tropics, either through low total input use which is often the case in sub-Saharan Africa (SSA), or because of excessive use of one nutrient input (N in Chinese rice culture, for example) which entails accelerated mining of soil nutrients such as K and micronutrients that are not applied. In the semi-arid parts of SSA where traditional fallow cycles no longer exist because of high population pressure and environmental degradation, soil fertility is reduced to a level that can just support a low-output subsistence level, often rightfully nicknamed as ‘sustainable poverty’. To use a phrase used by the farmers on the Adja Plateau in Benin to indicate soils that have become too exhausted for cropping: soils become ‘comatose’. This is the time that the farmers leave the soils to the ‘oil palm fallow’ which restores soil fertility for the next round. The oil palm fallow is an agro-forestry technique that has been developed locally and that benefits from the multipurpose nature of the oil palm tree, including its (distillable) palm wine (Brouwers, 1993).

The claim that mineral fertiliser is the only solution for the soil fertility problem sounds hollow in light of decreasing access to fertilisers in the south. It is time for a rethink, time for a more imaginative, responsive and adaptive approach to the problem of soil fertility management along the lines of the flows listed in Table 1. Cuba constitutes an interesting example of agricultural revival (forced by circumstances though), which is not based on fertilisers. It took place after the sudden end of the Cold War and the collapse of the Soviet Empire in 1989 which deprived Cuba of imported fertilisers and fossil fuel. As a result, Cuba had to invest in alternative forms of agriculture, including INM strategies such as nutrient recycling (FL in Table 1) and reuse of organic town ‘waste’ (IN 2). This effort apparently has been successful. Food production which dropped by some 30% after the Soviet collapse, has risen steadily and there are no food shortages on the island now, even though the land was severely degraded, still is densely populated, and suffers from an economic blockade (Carney, 1993; Wilson and Harris, 1996). Reijntjes et al. (1992); Pretty (1995) and Reij et al. (1996) report many similar cases which support the authors’ conviction that there are feasible and effective alternatives to the use of mineral fertilizers alone, covering the entire spectrum between so-called high and low-external input agriculture (HEIA–LEIA). As INM is both a technical and a social issue, ‘hybrid’ approaches are needed which combine causal logic with reference to things and the logic of reasons with reference to human activity (Richards and Ruivenkamp, 1994; Röling, 1997). The objective of this paper is to provide guidelines for a new praxeology to facilitate the INM learning process. This praxeology combines both the logics mentioned above, and builds bridges between fundamental and applied sciences.

2. The HEIA–LEIA spectrum for INM

2.1. Characterizing HEIA and LEIA

Over the past 20 years, it has become commonplace to distinguish between high (HEIA) and low (LEIA) external input agriculture (Reijntjes et al., 1992; Kieft, 1993). A certain amount of stereotyping in making this distinction cannot be denied. But it is, on the whole, useful to distinguish between the two types, if only because they also represent two major contrasting agricultural development metaphors. Regarding HEIA from a nutrient viewpoint, the focus is to obtain high production (OUT 1), mainly by using mineral fertilisers (IN 1; Table 1). HEIA strongly depends on the combination of chemical inputs, hybrid seeds, mechanisation based on fossil fuels, and often also on irrigation. It is capital and science-intensive and highly market-oriented (though usually subsidised in one way or another and with important externalities).
Other features are repeated monocultures and genetic uniformity (Reijntjes et al., 1992).

In LEIA, inputs $\text{IN } 2$ and $\text{IN } 4$ (Table 1) play an important role, and actions geared at the reduction of $\text{OUT } 2, 3$ and $\text{OUT } 5$ are more common than in HEIA systems. Also, the internal recycling of biomass on the farm ($\text{FL } 1-5$) tends to play a more dominant role. Chambers (1986) has identified LEIA as the typical form of agriculture in the vast, diverse and risk-prone rainfed areas in the south, which still has much scope for improvement. Wolf (1986) estimated that some 1.4 billion people, or about one quarter of the world’s population, depend for their livelihood on this type of agriculture. In many LEIA areas, population growth exceeds production growth. As new technologies to intensify land use have not been developed, are not known locally, or cannot be afforded by local people, farmers are often forced to mine their land (Reijntjes et al., 1992). However, to equate LEIA with degraded and stunted forms of traditional farming systems would be mistaken. It is now generally recognised that very modern, knowledge-intensive, and productive but ecologically-sound LEIA systems exist. In such systems, crops, trees, herbs and animals not only have productive functions, but also ecological ones, such as the production and recycling of good-quality organic matter, sustenance of soil life, improvement of the micro-climate, erosion control, sustenance of genetic diversity, shading, etc. These functions contribute to the continuity and the stability of the farming system (Lightfoot et al., 1994; Pretty, 1995).

A major setback of LEIA systems is their high labour demand, and the risk that through lack of nutrient inputs from outside the farm, the system may gradually approach the level of ‘sustainable poverty’ that was mentioned before. Saving nutrients from being lost from the system (common in LEIA) is not the same as adding new nutrients to the system (common in HEIA). Scientific research has clearly revealed that the combination of adding ($\text{IN } 1$) and saving ($\text{IN } 2$, $\text{FLs}$) provides highest agricultural output ($\text{OUT } 1$) as well as highest fertilizer use efficiency for crop production ($\text{OUT } 1/\text{IN } 1$). The organic matter acts as a nutrient-binder, thus delaying losses of fertilizer nutrients to the environment ($\text{OUT } 3, \text{OUT } 4$). Moreover, it slowly releases its own nutrients in the decomposition process, extending crop nutrient availability over a longer period of time.

### 2.2. INM technologies in HEIA and LEIA agriculture

Declining soil fertility can occur under both HEIA and LEIA, as shown by Van den Bosch et al. (1998). A high nutrient input level in cash economies of Kenya’s tea and coffee zones in Embu district, for example ($\text{IN } 1, \text{IN } 2$), is accompanied by high output levels ($\text{OUT } 1$). Net nutrient depletion in such areas is higher than nutrient depletion in the vast semi-arid zones in the east of the district, where farmers graze their cows on the commons and indirectly import nutrients ($\text{IN } 2$) by kraaling them inside the farm during night. Table 2 shows some of the major HEIA and LEIA technologies in Kenya that relate to soil fertility management, and their impact on the flows listed in Table 1. The ‘technology of last resort’ is INM, combining elements of available technologies in a way that best suits the local agro-ecological conditions and the farmers’ means and interests. It tries to make optimal use of the production factors land, labour and capital, with farmer learning and decision-making as the major driving forces from within, and conducive policies, support institutions and deliberate facilitation of technology and knowledge development as external forces.

INM is relevant for both HEIA and LEIA systems (Table 2). In the former, the move to INM can be seen as a response to a second generation problem of years of high fertiliser use. In the USA, USDA Cooperative Extension Service and Texas A & M Agricultural Extension Service (1997) have mounted a major extension programme in 53 states with the prime aim of getting farmers to use only that amount of fertiliser that they need, mainly because of the serious threat to water supplies from non-specific source farm run-off. In the Netherlands, a whole legislation is emerging around the use of minerals. In the 1980s, the country produced about 1 tonne of liquid manure in excess of crop needs for every man, woman and child (Van der Meer and Hedin, 1989). Nevertheless, most farmers used to apply mineral fertilisers quite independently from their use of manure. Given its intensive agriculture, this made the Netherlands the highest user of nitrogen (N) per ha in the world. In response, highly contested legislation to regulate the mineral use, and to make the farmers accountable for their emission into the environment, has been enacted. Also educational programmes, such as ‘Integrated
Arable Farming’, combining IPM and INM have been started, with mixed success (Van Weperen et al., 1998). Where INM is concerned, farmers are encouraged to manage mineral flows across rotations, by diligent use of nitrogen fixing crops, by measurement of mineral contents of animal manure, only using fertilisers to complement them, and by introducing various measures which farmers themselves can use for precision fertilisation. The latest development in this respect is ‘precision farming’ which allows dealing with within-field diversity in particular conditions by using farm machinery equipped with a global positioning system and an on-board computer (Bouma, 1997).

The problem in LEIA is one of ‘too little’ rather than ‘too much’, a totally different challenge for INM. Increasingly, farmers are becoming aware of the rundown of their soil fertility as one key aspect of a general degradation of their environment. In some areas in Africa and Latin America, enough land remains to practise slash and burn techniques, thus destroying the remaining forests. Unless special measures are taken, this appears to be the easiest alternative for the local people. In further phases of the degradation of traditional systems, there is no more land for such practices, fallow periods rapidly shorten, and farmers come face to face with the Malthusian, apocalyptic scenario of complete breakdown of the traditional system. There are, however, Boserupians, who suggest that reaching such a state or coming close to it is a necessary condition for doing something about it, because it is only then that the costs of more of the same are high enough for seriously considering alternatives. Hopefully, social learning helped by efforts to raise awareness about the nature and causes of the breakdown of traditional systems can help to bring forward the moment when this occurs. Lightfoot and Noble (1993) for Malawi, Ndiaye and Sofranko (1994) for West Africa, Tiffen et al. (1994) and Pretty et al. (1995a) for Kenya, Brouwers (1993) for Benin, and Reij et al. (1996) for different parts of Africa provide evidence that high population density and degradation can lead to concerted local effort to turn around the situation.

It seems that the HEIA–LEIA debate has lost much of its relevance as truth seems to lie midway. INM relates to both, and given the fact that INM has many different appearances, depending on the local situation, there is no need to stick to the HEIA–LEIA polarisation in the rest of this paper. Nonetheless, it is useful to revisit its development in the light of the proposed shift in praxeologies discussed below.

3. Two praxeologies: which for INM?

Röling and Jiggins (1998) distinguish two major praxeologies of agricultural innovation, i.e., transfer of technology and facilitating learning. A comparative analysis, using five elements, allows drawing clear theoretical distinctions between them. Table 3 shows that the two praxeologies are internally very consistent but totally different.

Transfer of technology is the praxeology that is most familiar. It has been the basis for years of investment in research and extension, with the Training and Visit System as a case in point. It is the model that is credited to have driven the Green Revolution.

Table 3
Matrix showing different praxeologies underpinning innovation in agriculture (Röling and Jiggins, 1998)

<table>
<thead>
<tr>
<th>Farm practices</th>
<th>Transfer of technology</th>
<th>Farmer learning</th>
<th>Facilitating learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilising science-based uniform component technologies</td>
<td>Adoption</td>
<td>Becoming expert at observation, inference, anticipation, and applying principles (usually in learning groups)</td>
<td></td>
</tr>
<tr>
<td>Transfer (demonstration)</td>
<td>Institutions ‘calibrated on science-practice continuum’</td>
<td>Participatory non-formal education based on discovery and experiential learning</td>
<td></td>
</tr>
<tr>
<td>Subsidies on fertilisers and pesticides, high investment in research and extension</td>
<td>Prohibitions of pesticides, levies on nutrient emissions, protection of green labels, removal of subsidies on chemicals</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Support institutions</th>
<th>Running the farm as a sustainable agro-ecosystem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutions ‘calibrated on science-practice continuum’</td>
<td>Participatory non-formal education based on discovery and experiential learning</td>
</tr>
<tr>
<td>Decentralised learning network of trained farmers and trainers</td>
<td></td>
</tr>
</tbody>
</table>

Conducive policies ||
|------------------|------------------|

Many development practitioners cannot imagine any other form of promoting agricultural innovation. Indeed, transfer of technology has worked tremendously well in some HEIA areas in spite of a certain degree of coercion in the adoption strategies (Röling and Van de Fliert, 1994, 1998). It has particularly worked well for disseminating information on simple substitutes for inputs that the farmers were already using in established farming systems (e.g., new seed for familiar crops, fertilizers, new planting dates or densities). It also worked well where environmental conditions were fairly uniform across fields and seasons and broad extrapolation from research trials more or less justified (such as in flat, irrigated areas).

At present, however, the focus on technology transfer is waning for several reasons. Where the model breaks down especially is where new management approaches/systems are needed that must be tailored and adapted in a site-specific way to highly variable and diverse farm conditions, or where year-to-year changes in management are needed to respond to high variation of climate and pest population. Farmers must have much deeper understanding of the underlying processes (nutrient management, pest management, crop interactions) and must learn to assess various options for different conditions. They must also work out a lot of details themselves, because of the unique conditions on their farms, especially in the highly diverse hillside or dryland areas with many micro-niches, high soil variation, and crop and tree mixes. The alternative approaches are also needed where farmers are experimenting with introduced tree or crop species that have been little researched (at least under local biophysical conditions). The transfer of technology is inadequate for handling land management changes which require joint planning and negotiation among multiple producers, such as microwatershed management or protection of fields from animals. It has not worked for the vast LEIA areas, whereas in HEIA areas, farmers return to land races as yields of high-yielding cultivars stabilize for a variety of reasons. Moreover, structural adjustment is adversely affecting the large, monolithic public research and extension establishments, and it is accepted generally that the model has worked only to a limited extent. Many previous observers have called for an alternative (e.g., Chambers and Jiggins, 1987).

The second praxeology, facilitation of learning, is only emerging now on the basis of learning from the new practice. In efforts to introduce sustainable practices, such as Indonesia’s IPM Training Programme (Röling and Van de Fliert, 1994, 1998) or the Dutch innovation project introducing ‘Integrated Arable Farming’, it is clearly seen how the five elements of Table 3 are operationalised (Van Weperen et al., 1998). The praxeology is internally consistent and is crystallising from experience. That experience shows that it is not possible to introduce ecologically-sound practices, such as IPM or INM, through mere transfer of technology (Agudelo and Kaimowitz, 1989; Matteson et al., 1994). The following section shows why INM must be facilitated according to the second praxeology.

4. The praxeology for INM: facilitating learning

So far INM has mainly been described in technical terms. However, it would be a mistake to ignore its crucial learning dimension. INM can only be carried out by farmers who are experts at managing their complex soils and who are able to capture the opportunities provided in the local situation to improve soil fertility. This calls for a totally different praxeology with respect to agricultural innovation than the still prevalent conventional one. It is especially with respect to its learning dimension that INM can benefit from IPM. In fact, it is the FAO-assisted IPM Training Programme in Indonesia that has pioneered a totally different approach to agricultural innovation and tested it under field conditions, scaling it up to a point where more than 400 000 small-scale rice growers have now been trained (Röling and Van de Fliert, 1998). It is obvious that, just as IPM is not primarily about bugs, INM is not primarily about soils. In fact, nutrients are just another entry point for the new approach, capturing the imagination of people everywhere as more evidence becomes available of successful farmer-carried initiatives. The realisation dawns that agriculture cannot be developed without banking on the intelligence, creativity and competence of farmers. Instead of on adoption, the emphasis now is on learning. Farmers become experts, not by adopting science-based technologies, but by becoming better learners. Enabling farmers to learn has a series of implications which are given below.
4.1. Observation

Farmers must be able to observe, as this is the basis for diagnosis, monitoring and feedback (information about the effects of one’s action). Observation implies (a) routines for looking (e.g., systematic and routine looking at sampled events); (b) indicators and simple test kits for the state of affairs, i.e., for values of crucial variables, such as pH, organic matter content, moisture content, and nutrient availability (Snapp, 1995); and (c) registration of processes (flows) and states (balances) in maps, records and diagrams which allow comparison across time and space. Observation (a), (b) and (c) still have to be developed for INM. Farmers who participated in the Kenya-based NUTMON project (Van den Bosch et al., 1998) claimed that they learned much from their farm maps which allowed them to distinguish between the different primary production units on their farms, and from the record keeping which they started to do to help them participate effectively in the research project (which requires them to provide detailed information on resource flows once a month). One farmer had coupled record keeping about nutrient flows with economic book keeping. This opens exciting possibilities for linking nutrient and cash flows, and calculation of the percentage of farm income that is derived from the soil nutrient stocks, as shown by the NUTMON group (De Jager et al., 1998).

4.2. Observation aids

Farmers must be provided with the observation aids, which proved relatively easy in IPM, but may be less easy in INM. In other words, this is a challenge. Instead of soil mapping for the farmers, scientists should increasingly support soil mapping and analysis by the farmers. Many promising experiences have been recorded:

- Defoer et al. (1995) and Defoer et al. (1998) adapted the resource flow mapping methodology developed by Lightfoot et al. (1994) to smallholders in semi-arid conditions in Mali to the point where farmers were learning to self-improve resource flows on the basis of the maps they had made.

- In Australia, Hamilton (1995) developed a Participatory Learning and Action Research approach which uses rainfall simulators, soil cores and other tools to support farmer experiential or discovery learning about tillage practices which are most effective for the soil moisture retention. Hamilton showed that such experiential learning of the principles at work allowed farmers to draw their own conclusions about action in a wide range of conditions. Similar work was carried out in Zimbabwe (Hagmann et al., 1995). The authors did imaginative work in demonstrating the effects of rainfall on various tillage conditions on run-off and erosion, by using a simple rainfall simulator, featuring an iron container which allowed measuring runoff and leaching under various tillage conditions of soil in the container. The rain was provided by a watering can.

- The Landcare movement in Australia has experimented with a great many tools for discovery learning, including GIS software, soil profiles, piezometers, resource mapping, up-scaling farm-based soil maps to catchment maps, etc. (Campbell, 1994). There are many other tools which the farmers could use, such as augers, pH paper, bio-assays (growing plants in pots, i.e., using plant growth to show fertility instead of chemical analysis; e.g. Snapp, 1995).

4.3. Interpretation, inference and anticipation

Observation cannot be done with an empty mind. Observation triggers mental processes which inform effective action. Learning to draw lessons from observation requires a great deal of theoretical knowledge about variables and processes. In IPM this typically involves the life cycles of pests, the relationships between pests and natural predators (‘thresholds’), and the effects of pesticides in terms of pest resurgence (the ‘pesticide winter’) and resistance. These tools still have to be developed for INM. NUTMON has so far largely focused on NPK as ‘invisible’ soil and applied nutrients in their molecular form (Smaling and Braun, 1996; Van den Bosch et al., 1998). It seems that much work must be done with respect to the development of ‘farmer theories’ about the interactions between the nature of base material (especially texture), moisture content, organic matter content, and
soil life, and the impact of mulching, tillage practices, contour ridging, the nature of different crops, biological N fixation, etc. Developing and testing farmer ‘theories’ about these issues is a key aspect of the work proposed here.

4.4. Principles and concepts

Farmers must be helped to acquire principles and concepts for nutrient management. That is, farmers are not experts on the basis of a body of memorized knowledge which they have acquired from others. They are experts because they can apply a number of internalized principles in diverse situations and adapt what they are doing when circumstances change by changing the principles. Facilitating farmer learning of principles is difficult. It can not be done easily on the basis of words (book knowledge, lectures, etc.). Again, discovery or experiential learning has been shown to be a key avenue to impact. In IPM, a training method based on experiential learning was developed which engaged small groups of farmers in so called ‘agro-ecosystem analysis’. This meant careful decision making about ‘thresholds for pest management activity’ based on a careful analysis of the evidence collected from systematic field observation. Defining these thresholds was a sensitive issue in IPM which changed from simple equations based on the numbers of pests and predators, to economic thresholds based on equations featuring costs and benefits of pest control activities, and finally to simple reliance on farmers’ informed decision making. Developing such tools for discovery learning about INM principles is another key activity proposed here. Resource flow mapping, as developed in Mali, or ‘mineral balances’ as developed for farmer use in the Netherlands might be the basis from which to start. Combining flow diagramming for primary production units with nutrient balances at the farm level seems to be an interesting possibility to follow.

4.5. Concrete alternatives for effective action

Of course, all the farmers’ learning about soils is to no avail if there are no concrete alternatives for effective action. Given the high diversity and variability of African smallholder environments, no blanket recommendations can be given. Again the focus would be on a higher level of abstraction, i.e., principles for solutions which farmers could apply in their locality-specific situation. The NUTMON model, specifying INs, OUTs and flows within the farm (Table 1), could provide farmers with concrete leads to strengthen INs, limit OUTs and maximize internal flows. Principles involved include those listed in Table 2, but also less obvious actions such as recycling urban waste and effluent, capturing nutrients from common or open access property resources (e.g., leaf litter from forests, manure from animals grazing on the commons, sea weed collection), and developing complex multi-industry enterprises by groups of farmers (typically women), involving e.g., cocos oil processing, keeping pigs fed on waste of the oil processing, and growing vegetables for the urban market with pig manure (Dangbegnon, 1998).

4.6. Farmer networks and platforms

The essential focus is on developing farmer capacity to identify and exploit opportunities for applying one or more of the above principles in their locality-specific situation. Developing this capacity would typically include developing local farmer networks or platforms at which such opportunities could be discussed and developed. Often collective action, involving the transport of urban wastes to farms, the use of common property resources, the development of complex multi-industry enterprises add value in the local situation.

4.7. Integrated curriculum for farmer INM training

The participatory development and testing of the ingredients mentioned in this section need to be integrated into a curriculum for farmer training which is developed and tested with the farmers. Necessarily, such a curriculum should focus on non-formal farmer education. The ‘Farmer Field School’ as developed in Indonesia’s IPM programme is one such possibility. It involves groups of 25 farmers from the same locality meeting some 12 times for 3 h once a week during the growing season, during which they follow the development of the crop in an experimental field, featuring an IPM and a conventional treatment and apply the agro-ecosystem analysis mentioned above.
4.8. INM trainers

INM training assumes the availability of trained INM trainers. IPM’s success is Indonesia is largely dependent upon the great attention over some 6 years to developing a cadre of Indonesian IPM trainers before the start of the actual IPM training programme. During the programme, the attention to cadre training has never been relaxed. Starting small, the number of these trainers was gradually built up, as trainers began to train other trainers. Now there are several hundreds of IPM trainers, divided into three ‘grades’. These trainers are by no means people who follow routines. Their expertise, built up during a year’s systematic training, allows them to apply principles of adult learning in a great variety of circumstances. They are the prime collaborators of the scientists in developing the curricula for IPM farmer training. The IPM experience shows that, in the later stages of the project, a beginning can be made to select farmers to act as trainers of other farmers. In IPM, the majority of farmers has now been trained by other farmers, often financed from local government resources. This approach provided the key route to scaling up the impact of the programme. It was chosen following disappointing experiences with regular government extension agents for large scale IPM training. Hence, INM-training must also start with very careful selection of a small cadre of INM trainers, which can gradually expand over the years as qualified trainers train other trainers and as the trainers help to develop the programme conceptually and methodologically.

4.9. Institutional support framework

In all, the approach to INM training advocated above requires great and sophisticated attention to the institutional support framework at a sufficiently high level. Establishing such an institutional framework is likely to be fraught with tension among competencies of various stakeholders such as research institutes, extension services, foreign consultancy agencies and donors. Unless a protected niche is developed which allows INM training to establish and take off, it will be dissipated before it has a chance to prove itself. This point requires very careful and strategic decision making at the highest political level. Such decision making is considerably facilitated by the established seriousness of the threat to national and local food security (and hence political stability) posed by soil nutrient mining, and by the established unsustainability of present farmer incomes which are increasingly based on nutrient mining (De Jager et al., 1998). INM training can only lead to success if it is established, supported and protected at the highest political levels, involving national governments, international institutions such as the World Bank and the United Nations, and multi- and bilateral donors.

5. Towards a concrete strategy for facilitating INM

The strategy proposed here for facilitating INM learning is made up of three phases, i.e. (i) a participatory rural appraisal (PRA), (ii) diagnostic and technology development activities in a learning group elected by the community, and (iii) feedback and consolidation. The strategy is due for testing in Phase II of the NUTMON project in sub-Saharan Africa (Smaling et al., 1996). Eventually, Farmer Field Schools and curricula for farmer training have to be developed based on the technologies developed and consolidated during (ii) and (iii).

5.1. Participatory rural appraisal

The objective of the PRA is to create shared awareness, within the community identified and among the facilitators, of the community’s degradation problems at the farm and higher system levels (Bojanic et al., 1995; Pretty et al., 1995b; Engel and Salomon, 1997). The PRA ideally starts with a ‘mandate’ from the community. That is, the purpose of the work will be explained at a community meeting and opportunities for improvement will be discussed. The PRA will thus be a legitimate activity in the community and people will see a reason for contributing to it.

The PRA itself will use various established PRA methods (Pretty, 1994; Pretty et al., 1995b), such as farm walks, transects of the village area, mapping the watershed of which the village is a part, retro-active social mapping, especially focussing on the development of the village’s natural resources in the past 40 years (Sadomba, 1996), ranking for priority setting, etc. The intention is that the PRA leads to a shared
‘common construction’ of the resource degradation in the village, which may not be the ‘objective truth’ but which comes closest to an ‘agreed-upon reality’ as perceived by the group. In addition to the established PRA methods, INM-supporting techniques such as participatory air and satellite photo interpretation, digging soil pits, soil sample testing, etc., may come in handy.

The results of the PRA indicate how farmers rank problems with regard to resource degradation, which concepts they use to describe and classify these problems and how fertility problems are noticed on the farm. The reporting of the results from the PRA should cover all topics raised by the community. At this stage of the research, a focus on INM is premature. The PRA would end by reports from the team of people who did the PRA (explicitly including community members). Moreover, the report to the community must not only reflect what it already knows, but also include some new perspectives and opportunities provided by the scientists. The PRA hopefully ends with a collective decision on how to proceed. It will be suggested that the community selects a ‘learning group’ of people who give resource degradation high priority and who want to be involved in active experimentation and development work.

PRA is a method to obtain a broad overview of a complex situation. It makes full and immediate use of the knowledge, experience and insights of local people and makes their priorities explicit. However, PRA as a method can also be used extractively, i.e., only to the benefit of the visiting researcher who wants to make use of local people’s knowledge. That is definitely not the purpose here. Nor is it a purpose of a PRA to provide statistical analysis or quantitative measurements (Hamilton, 1995).

5.2. Work in learning group

The learning group elected from the volunteers by the community will be engaged in diagnostic analysis and participatory technology development (PTD). This phase could be called ‘collaborative INM development’. The learning group can, of course, decide to split in various sub-groups or focus groups of people who want to involve themselves in specific problems. Such groups could be linked to the existing clubs or networks.

The objective of the learning groups is to learn about soil fertility processes and INM at the field, farm, village and micro-catchment levels. The methods used at this stage are not as readily available as in the case of PRA, but need to be adapted from the work of others, or ‘invented’ together with the farmers.

An obvious method with which to start is the resource flow analysis developed by Lightfoot et al. (1994), Defoer et al. (1995, 1998) for the farm level. According to these authors, it is most efficient to start the group work with a walk around a farm. During this walk the researcher should identify nutrient flows, with Table 1 in his mind, and compare this with the flows mentioned by the farmers. The same holds for Table 2 when it comes to discussing technologies that are already in place. Meanwhile, the researcher should attempt to explain his perception of nutrient stocks and flows to farmers, while being reciprocated through local vocabulary, perception and classification systems. Attempts should be made to integrate these aspects, and proceed in such a way that both the farmers and researchers are able to learn optimally and interpret by interaction. Results can be exchanged verbally and through drawings. A strong mutual open mindedness and empathy is essential for this exercise to be successful.

Through this collaborative process, farmers and researchers can exchange ideas about how nutrient flows and technologies (theories) can be integrated into existing farming systems (practice) and how degraded natural resources might be rehabilitated. Moreover, it is a method to explore diversity of management practices (Hamilton, 1995). All aspects which are considered important by the farmers should be included in the drawings. While some groups are concentrating on the discussion at farm-household level, other groups can work on flows within the village or even the watershed. In this way a more complete picture is created of the nutrient status of the agro-ecosystem, which allows for a better identification of constraints and solutions. When this first step of diagnosis through nutrient modelling is completed, the discussion on suitable ways to improve the problem situation can be started through collaborative experimental and experiental solution building through PTD. PTD refers to approaches that aim at strengthening local capacities to experiment and innovate. Farmers are encouraged to generate and evaluate
indigenous technologies and to choose, test and adapt external technologies on the basis of their own value system (Reijntjes et al., 1992). PTD is gaining increasing recognition, mainly by NGOs (e.g. Rhoades, 1984; Chambers and Jiggins, 1987; Defoer et al., 1995, 1998). The major role of the researcher is not to be a specialist in designing the experiment, but rather to strengthen farmers’ capacities to systematise their learning process. There are no fixed rules, but the basic idea is to improve, reinforce and add to farmers’ experimental practice. The major steps are (i) to review farmers’ experimental practices, (ii) to plan and design the selected experiments with the farmers, and (iii) to develop protocols for evaluation of the experiments (Jiggins and De Zeeuw, 1992).

5.3. Feedback and consolidation

An essential element of the approach is the regular feedback of pilot farmers’ results and their reflections to the village. Lightfoot and Noble (1993) pointed out that the flow models are an useful tool for monitoring, as farmers can update their models on a regular basis using the initial plan diagram of their farm. Changes of flows can be easily identified when the farmers produce time–series models of their farming operations. Wherever possible the amount of material, frequency of flows, and monetary value are recorded. During farmer workshops and feedback sessions farmers can exchange ideas on the differences in INM and possibilities for improvements (Defoer et al., 1998). Researchers can comment wherever necessary, but are facilitating rather than in the forefront. They should support the decision making process rather than the outcome.

6. Risks and opportunities

Pretty and Chambers (1993) indicate that for the learning process to be sustained, (i) participatory methods have to be available, (ii) an interactive learning environment should encourage participatory attitudes, implying that farmers and researchers and other stakeholders must be prepared to learn from each other, and (iii) institutional support should encourage the learning. If these conditions are not met, for example because the initiative for participatory development relies on one person or a small group, the initiative will disappear when the person or group moves or is moved out. The fundamental difference in social status between the farmers and researchers and among farmers may hamper the creation of an open discussion (Merril-Sands and Kaimowitz, 1989; Nas, 1997). Researchers have to learn to listen. Also the context in which participation takes place is of great importance. If farmers do not trust facilitators because of former dismal experiences, it will be very difficult to share ideas and perceptions and to make joint decisions.

PRA has a number of pitfalls, relating to biases in team composition, distance to economic centres, gender, etc. Chambers (1980) warns that PRAs can easily become quick-and-dirty, whereas it better be relaxed-and-clean (Mikkelsen, 1995), with due attention for flexibility, the use of different research techniques, interdisciplinarity and a process-based approach towards iterative knowledge generation and learning. An important criticism on PRA and related research methods is that they do not provide data which can be analysed statistically. The question whether or not statistics is the best tool to be used to analyse the complex conditions under which the farmers work has however, hardly been asked. De Steenhuijzen Pipers (1995) who worked at village level in northern Cameroon indicated that whereas researchers strive at low coefficients of variation around the mean, farmers see diversity as a blessing and even promote it for reasons of risk-aversion.

As the output of the collaborative nutrient modelling process is time and site-specific, it is hard to extrapolate results. But it is not so much the results which need to be extrapolated as the social process. This means that, even though the results of the learning processes might be totally different, the learning process itself may be applied across a wide range of situations. Nonetheless, experience with introducing ecologically-sound agriculture has so far focused especially on farm-level practices. Yet INM can hardly be imagined without farmers learning to take collective action to manage larger units, such as watersheds, village territories (e.g., Toulmin, 1993), multi-industry recycling networks, etc. Thus farmers must engage in building ‘platforms’ for learning and decision making which are commensurate with the hard system levels at which degradation is perceived to be manage-
able (Röling, 1994, 1995). The praxeology underpinning the facilitation of such collective action is being researched at present (e.g., Maarleveld, 1996; Dangbegnon, 1998).

7. Conclusions

1. Integrated nutrient management has multiple appearances. Its success depends largely on the means and the interests of farm families to invest in soil fertility.

2. For farmers to become better soil fertility managers, their knowledge of farming systems has to be interactively linked to more fundamental knowledge on processes that enhance the soil fertility. Objective scientific truth (if this at all exists) and farmers’ realities may not be the same, and ways have to be sought to bring the two together. This requires ‘social intervention’ and is a major challenge to social scientists in the field of INM.

3. A new praxeology, i.e., the theory informing practice which in turn feeds theory, is proposed to stimulate better livelihoods through better INM strategies. It leans strongly on successes in the field of integrated pest management. The praxeology leaves the traditional mechanism of transfer of technology behind, and rather focusses on the facilitation of joint learning. Key to this paper is the process of achieving this. Next comes the area-specific upscaling mechanism to reach larger communities.

4. A series of guidelines have been described that are essential for the praxeology on INM to become successful. In essence, it boils down to participatory rural appraisals, participatory technology development and feedback and evaluation. Further testing in different field situations is essential to find out whether INM has the same potential as IPM under the aegis of the joint learning praxeology.

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