MORE FOOD FROM FERTILE GROUNDS

Integrating approaches in order to improve soil fertility

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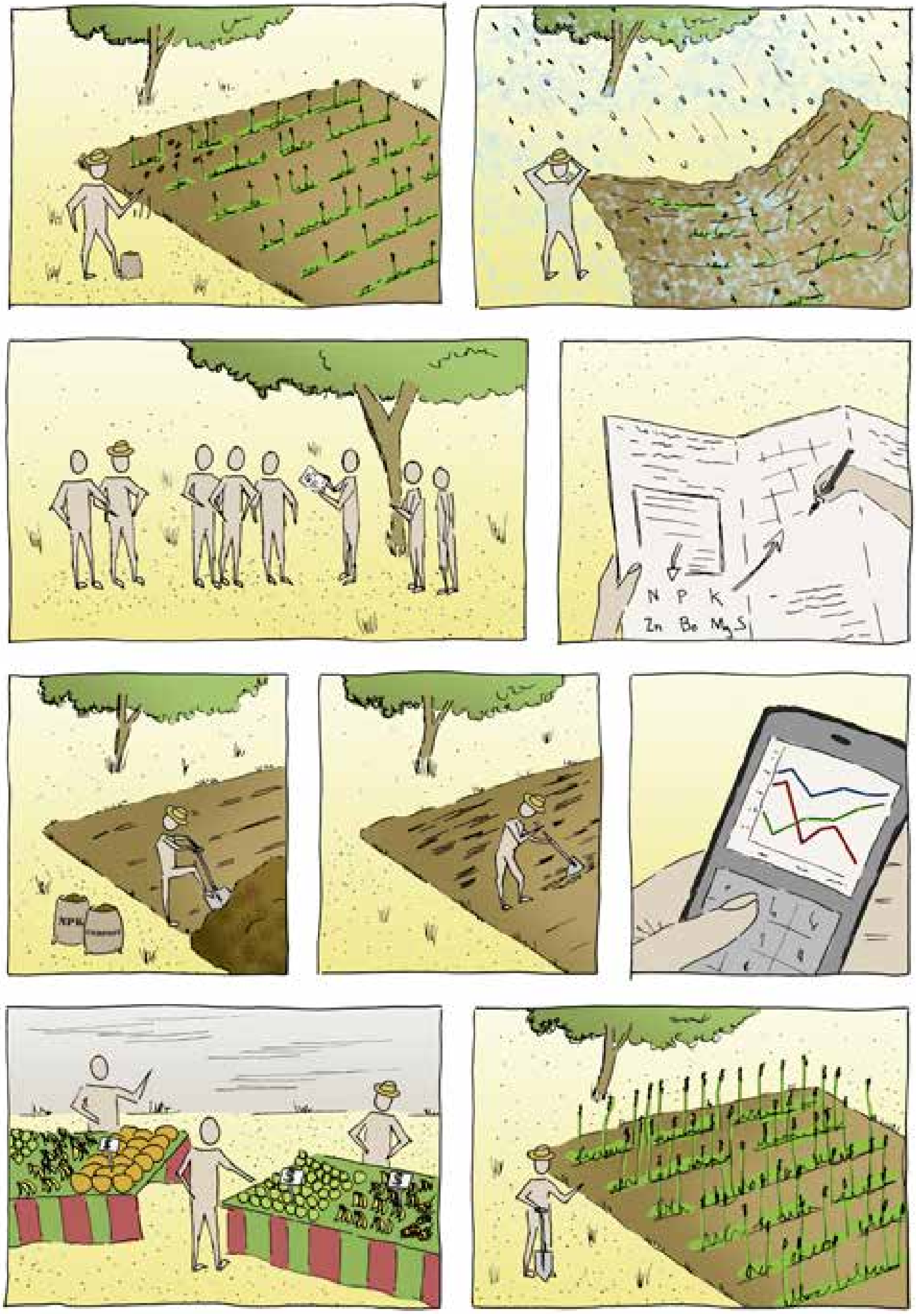

Cartoon representing a way to get out of the poverty trap (see page 7)

Colophon

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Content

Summary

Soils represent a major natural capital asset and have enormous potential to increase agricultural production while, at the same time, combating climate change and contributing to green economic growth. Yet, every year more than €3 thousand million is lost due to soil degradation. To unlock the potential of soils, nutrients need to be used more efficiently. This can be achieved by improving the recycling of nutrients, increasing organic matter content and applying fertilizers of the right type in the right amounts, at the right time and in the right place.

There are several pathways of change that have been proposed to increase the productive capacity of soils. However, with current trends – globalization, urbanization, resource scarcity and climate change – new approaches are required. In our view, such approaches should be based on Integrated Soil Fertility Management (ISFM), which includes the application of both mineral fertilizers and organic manures. Subsequently, ISFM should be supplemented with site-specific interventions and a better match between supply and demand of (locally available) nutrients to make the best use of available resources, reduce environmental impacts and enhance green economic growth.

The Fertile Grounds Initiative (FGI) was designed as an coordinated strategy of collaboration between actors in nutrient management at various spatial scales. It is based on eight subcomponents, which bring together the supply and demand of nutrients within a specific geographical area to make optimum use of site-specific interventions and available nutrients, supplemented with external imports. We expect the FGI to make a significant practical contribution to sustainable development in areas with limited soil fertility and nutrient availability, while at the same time resolving problems arising from nutrient excess in certain parts of the country and from (urban) waste streams, turning these into economic assets.

1. Challenges

Approximately 870 million people suffer from food insecurity worldwide. This figure is especially striking as many live in areas where there is a considerable gap between potential and actual production. Many live in regions where crop yields are very low and malnutrition is rampant. This situation will be further exacerbated by anticipated climate change, population growth and changing diets due to urbanization. The UN has repeatedly stated that food insecurity is the single greatest solvable problem facing the world today. We propose a new approach: the Fertile Grounds Initiative (FGI). FGI is an alignment of approaches of various institutions at different levels of scale. It brings together demand and supply of nutrients within a specific area in order to make optimum use of available nutrients, which are then supplemented by external imports.

'Food security is the single greatest solvable problem in the world (UN World Food Day, 16 October 2013). Improving soil fertility is critical to success.'

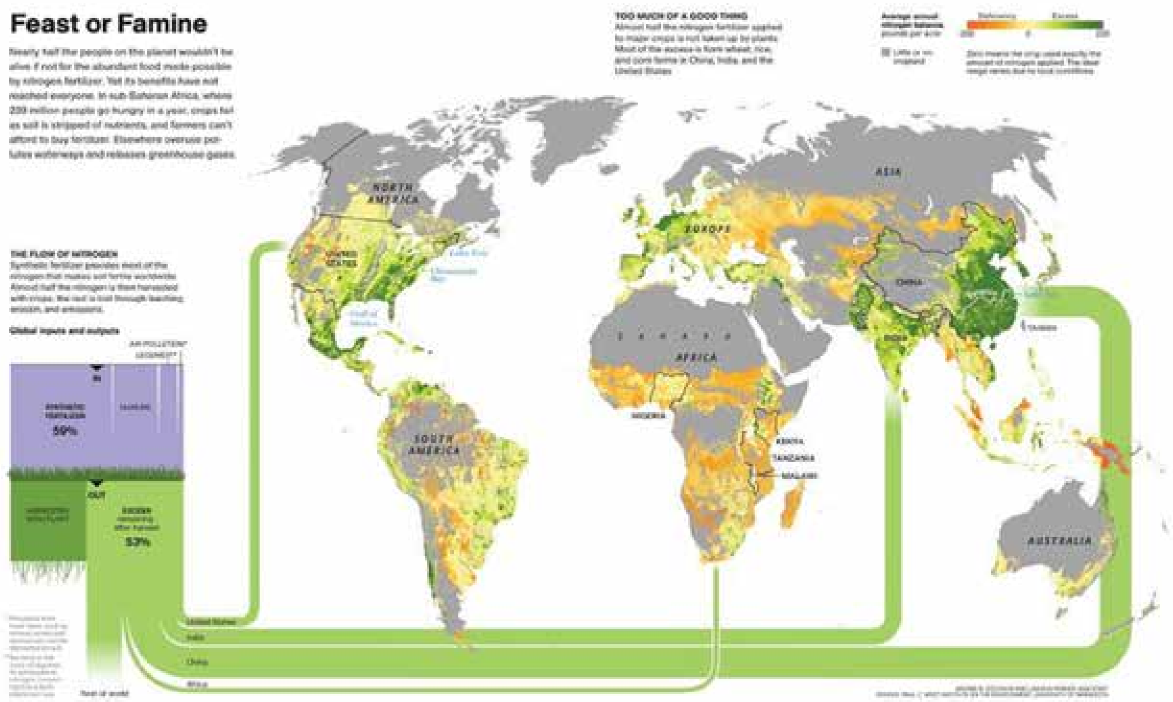
'Soil fertility as a proxy for nutrient cycling mechanisms determines the quality and productive capacity of the soil, and consequently the quality of food.'

Why should we do things differently?

Crops need light, water and nutrients to grow. Of these, light and temperature are the least and nutrients the most manageable production factors. However, whether manageable or not, recent trends have led to polarization of nutrients, i.e. an uneven distribution between accumulation and depletion areas, which more or less overlap with developed and developing countries. And this is no coincidence. Population growth, economic growth and changing diets, urbanization, globalization and climate change put increasing pressure on available land and change the way land is managed. Overexploitation is jeopardizing available land, and land acquisition (also termed land grabbing; one of the signs of increased land pressure) destabilizes local communities and disturbs global power relations.

Policy makers are increasingly aware of the paradox in attempting to combat nutrient emissions to the environment in developed parts of the world, while nutrient depletion is jeopardizing agricultural productivity in developing parts of the world. Nearly two-fifths of global average N inputs are lost from agro-ecosystems to the environment. This is both a valuable loss as an environmental concern and the amount is likely to increase, considering increasing numbers of livestock. Although livestock transform fodder and feed into manure, which is a very good organic fertilizer, this transformation by livestock is very inefficient.

The simple (but often oversimplified) solution to nutrient depletion is to import nutrients from external sources (for P and K from mines, for N through N-fixing plants from the air). Apart from rapidly escalating energy requirements and associated environmental threats, several studies have indicated adverse effects of their use in poorly managed farming systems. Moreover, global reserves of mineral fertilizers are declining, pushing up prices.



Box 1. Global nitrogen deficiency and excess (National Geographic 05/2013, with permission)

This figure shows the global nitrogen balance and the hotspots of nutrient depletion in large parts of SSA, South-America and South-East Asia. Hotspots of nutrient accumulation occur in Europe, North America, China, and India. Nutrient balances are useful signalling tools and, therefore, are frequently used as an indicator. However, they do not explain the different responses to nutrient depletion in different situations. For instance, the figure indicates severe nutrient depletion in Central Asia but, as these soils are generally considered very fertile, nutrient depletion is not the main threat to agricultural production there (in contrast to moisture and erosion; Karabayev, 2008).

Interest in soil fertility issues has recently increased among policymakers, leading to several (political) declarations that emphasize the importance of soil quality for sustainable development. However, despite these actions, soil nutrient depletion is continuing and sometimes worsening in developing countries (Box 1). Unlike other forms of environmental degradation, e.g. physical soil degradation such as gullies and landslides, pollution, cutting down tropical forests, etc., declining soil fertility is often invisible and, when it does become visible through cascading effects, it is often too late. Restoration is then only possible at very high cost. This is why immediate action is needed to fill the yield gap and stop further deterioration of the poverty gap (Figure 1).

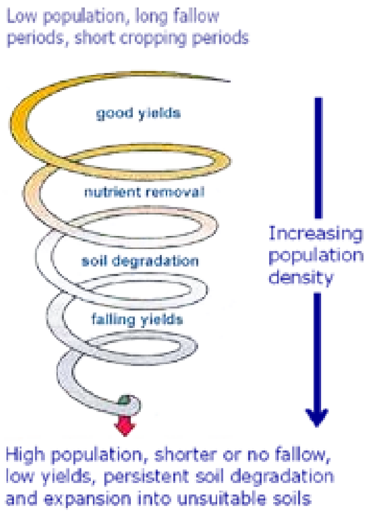


Figure 1. The downward spiral into the poverty trap

So what should our target be?

According to many (e.g. the Montpellier Panel, 2013; UNCTAD, 2013) a systemic change in agriculture is urgently needed to counter current threats. Key players in the required transition are smallholders. They have been and will continue to be the worlds' largest food producers. Paradoxically, they are also the vast majority (~80%) of the billion people suffering from hunger and malnutrition.

To reverse this trend a range of change trajectories can be anticipated. Figure 2 shows desirable changes: an increase in food production and resource use efficiency (the green line) that helps farmers increase food security (black dotted line) by becoming increasingly professional, working in a sustainable manner with other farmers (purple line), and finally, a reduction in costs per unit of produce (red line). It is important to take into account the actual situation of farmers in the field (represented by the three numbered boxes).

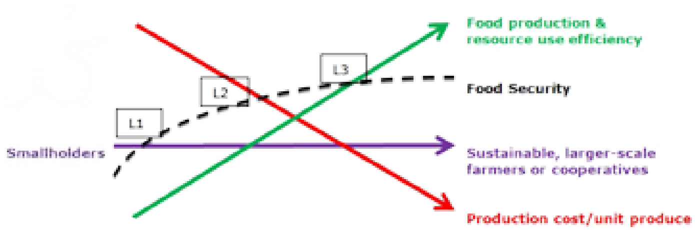


Figure 2. Envisaged transitions for farmers along three axes and the result: more food security. L1-3 = the actual situation of farmer groups 1-3 on the food security scale

In this document our main message is that maintaining and improving nutrient cycling mechanisms is essential. Soil fertility should be regarded as an investment that needs to be maintained, rather than as a production factor that can be augmented or depleted. Soil fertility represents an economic opportunity that is reflected in the price of land. Degraded land is virtually worthless.

2. The basket of interventions

Many interventions designed to increase soil fertility have been introduced. Basically, these can be subdivided into two distinct approaches:
i) interventions aiming at increasing the availability of nutrients through import of organic and mineral fertilizers and ii) interventions aiming at increasing the use efficiencies of available nutrients. Clearly, both are needed to develop highly performing, high efficiency food production systems. Yet, the two types of interventions are often introduced in isolation.

Interventions aiming at increasing the availability of nutrients

Interventions aiming at increasing the availability of nutrients through import of organic and mineral fertilizers can be further subdivided into: A) Large-scale initiatives designed to increase the use of fertilizer, and B) Small-scale demonstrations to achieve local validation of a variety of practices or technologies.

Both of these approaches have their advantages and disadvantages. Large-scale initiatives often lack the sense of ownership among farmers and tend to be expensive, whereas small-scale approaches tend to produce islands of success, with limited effects on the enabling environment (e.g. the supply chain and market access). We argue that there is no silver bullet. Rather, there are various ways to improve soil fertility that all have specific requirements for success. The challenge is to find the right package of interventions for a specific situation, as none of these interventions will solve the problem of low soil fertility on its own.

The use of mineral fertilizers can be increased through trade liberalization and by providing subsidies. The proponents of trade liberalization often refer to the example of Kenya, where maize yields rose considerably after economic reforms in the fertilizer sector, during which import quota restrictions and licensing requirements for fertilizer imports were abolished.

Subsidies are often seen as a catalyst for the use of mineral fertilizers. Supporters of this approach refer to the example of Malawi, where farmers buy vouchers at reduced costs and exchange them for fertilizers at a distributor who redeems the voucher at a designated

Box 2. The Malawi case

In the 1990s the government of Malawi introduced the Starter Pack Programme: all farmers received 10-15 kg of fertilizer and enough seed to plant 0.1 ha. Later this programme was converted into the Targeted Input Program and finally into the Agricultural Inputs Subsidy Program. The AISP is a universal voucher- based subsidy programme that allows farmers to buy 100 kg of fertilizer at about 20% of the market price. Since then maize yields increased substantially, but the total cost of the voucher system reached US$91 million (i.e. about 45% of the budget of the Ministry of Agriculture and Food Security and 5.2% of the national budget). An evaluation of the voucher system estimated that the benefits in terms of additional maize production were between 76 and 136% of the costs, leaving it ambiguous whether the programme can be justified on efficiency grounds (Minot and Benson, 2012). Comparable programmes are now being implemented in Rwanda and Burundi with support of the Dutch government.

government facility (Box 2). Although yields responded very positively to this system, abuse has also been reported and nutrient use efficiency was low, indicating wastage of nutrients. Chirwa and Dorward (2013) concluded in the case of Malawi that input subsidies can contribute to economic development in poor agrarian economies, provided that these subsidies also target market failures (in e.g. access to knowledge, input or capital).

is the most efficient legume grown on a large scale: it fixes up to 70% of its N requirements.

Conservation agriculture (CA) is designed to ensure sustainable, profitable agriculture through the application of three key principles: i) Minimum mechanical soil disturbance to maintain nutrients within the soil, reduce erosion and loss of water, ii) Creating a permanent organic soil cover to allow decomposition of

'We aim to concentrate nutrients in the root zone, but more and more nutrients are being lost through erosion and leaching.'

Interventions aiming at increasing nutrient use efficiencies

There are a wealth of technologies that can be used to enhance nutrient use efficiencies, ranging from stone mulch to seeds coated with fertilizers and from vermicomposting to foliar sprays. The proponents of most of these systems claim impressive results. Yet, none of them applies to all situations. Below we present some of the more popular interventions aiming at increasing the use and recycling of locally available nutrients.

Biological nitrogen fixation (BNF) involves symbiosis with leguminous crops such as beans, clover, soybean, alfalfa and peanuts. These crops allow rhizobia bacteria to fix N from the atmosphere into the root nodules. The fixed N is then available for the crop and after harvest the nitrogen remaining in stubbles and roots becomes available as an organic fertilizer. Soy bean

mulch that is left on the surface, and iii) Crop rotation with more than two species to prevent pests such as insects and weeds to enter the system (Jat, 2013). CA can have many beneficial effects, but start-up costs are high, because it takes considerable time and labour before CA systems are established and yields normalize.

Compost consists of organic wastes that are decomposed by aerobic micro-organisms. Compost has recently received renewed attention for its potential to reduce greenhouse gas emissions, sequester carbon and release valuable nutrients. Vermicompost is a special type of compost in which various worms create a heterogeneous mixture of decomposing vegetable or food waste, bedding materials and vermicast.

Soil amendments (also referred to as soil conditioners) are products that improve the physical quality of the soil, resulting in improved nutrient and water holding capacities. Most amendments contain one or more of the following constituents: bone meal, peat, coffee grounds, compost, coir, manure, straw, vermiculite, sulphur, lime, blood meal, compost tea, hydro-absorbent polymers and/or rock fertilizers. Soil amendments can offer an effective way to rehabilitate degraded soils, but often their adoption is low due to high costs and public opinion that is against external inputs of 'techno-products'.

The way forward: adopting a basket of options

The above-mentioned interventions show that there are various options for increasing soil fertility, but that each intervention has its own unique set of conditions to achieve success. Hence, there is no single, one-size-fits-all solution. The various interventions can be plotted in two dimensions (Figure 3):

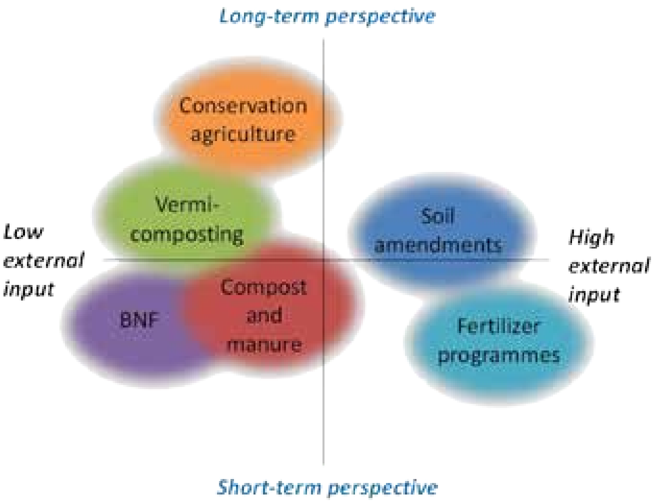


Figure 3. Interventions that address soil fertility differ in time perspective (short versus long-term) and input level. BNF = biological nitrogen fixation

- The economic dimension: interventions needing low inputs versus interventions needing high external nutrient inputs.
- The temporal dimension: fast responding interventions versus slow responding interventions.

Typically, high input, quick response interventions reflect a market-driven development pathway, whereas low input, slow response interventions typically reflect more ecological development pathways. Yet, there is scientific consensus that a package of interventions can integrate organic and mineral sources of nutrients. This concept is known as Integrated Soil Fertility Management (ISFM, Box 3).

Box 3. Integrated Soil Fertility Management (ISFM)

ISFM has been defined as 'A set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at optimizing agronomic use efficiency of the applied nutrients and improving crop productivity. All inputs need to be managed following sound agronomic and economic principles'. In ISFM, mineral fertilizers are the main way to increase yields and organic fertilizers can improve the efficiency of the mineral fertilizers. All soil-improving technologies have a cost in terms of labour and land. Further, as both mineral fertilizers and organic matter are scarce resources, ISFM focuses on how to manage them efficiently (Bationo *et al.*, 2012).

3. Closing cycles through linking scales

Conversion processes and the transport of nutrients take place across several spatial scales: from adsorption-desorption processes at the molecular level to global atmospheric interactions. Hence several authors claim that improving soil fertility requires a multi-scale approach (e.g. Sutton et al., 2013). However, at each distinct spatial scale different 'barriers to change' need to be overcome (Box 4). This is why nutrient management options at various spatial scales are assessed and actors are indicated that can help align these actions.

Box 4. An example from the Aberehech Desta farm in Ethiopia

Nitrogen (N) was used as a proxy for nutrient balances at various spatial scales and the results from this farm show that nutrients concentrate and diffuse at different spatial scales. 'Real' losses only occur at the field scale, where nutrient diffusion is at a maximum.

N balances at plot, farm, regional and national scale (kg/ha).

Field: wheat	Farm: Aberehech	Region: Tigray	Nation: Ethiopia
-17	31	11	10

Micro scale

Improving soil fertility can begin at the lowest level of scale by promoting positive interactions between crop biodiversity, soil biodiversity, and the productive capacities of soils in which micro-fauna and micro-flora play an important role. This can lead to the evolution of a new form of agriculture based on ecological principles, which are good for products that can be sold under special labels. However, when climate change alters soil factors to restrict root growth, the expected nutrient stress need to be taken into account.

Field scale

At this scale the effects of nutrient cycling are most apparent and even fields within a single farm can have very different levels of soil fertility (Figure 4). This

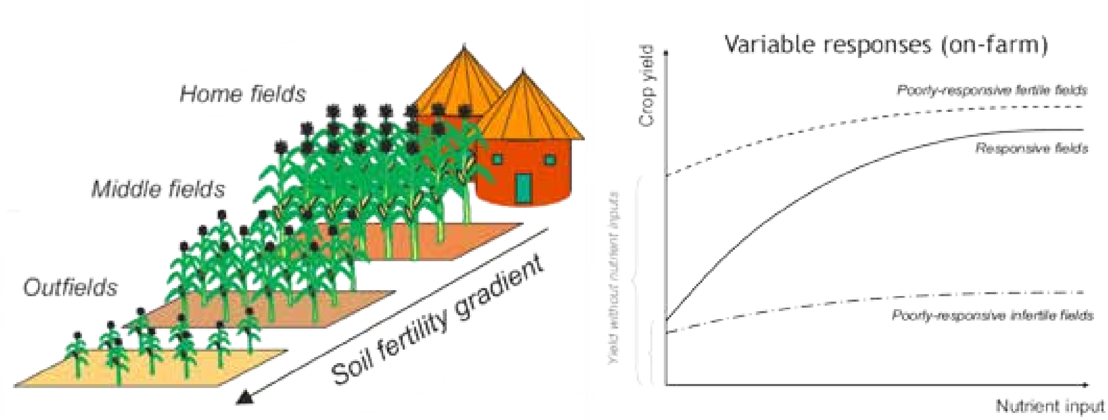


Figure 4. Within-farm variability of soil fertility (left) causes different responses to fertilizers (right, Tittonell et al., 2013)

can be due to differences in geographical settings, as well as soil and water management practices. Fertilizer recommendations for a field need to be tailored to both the demands of crops, cropping systems and the supply available in the soil. In this context, linking NGOs and agricultural development projects with national and/or international knowledge institutes is paramount.

Farm scale

An integrated farm approach helps farmers get a better understanding of their activities and a higher return on investments. The farm scale is decisive and also the most important for farmers. At this scale the cumulative effect of all farm activities become evident. That is why making an Integrated Farm Plan by the household is promoted. Performance indicators at the farm level, e.g. net farm income, gross margins, market share, etc. often refer to the past season, whereas investment in soil fertility require a long-term perspective. In this regard land tenure is key, as insecure land tenure adversely affects the willingness of farmers to invest in the long term and in quality.

Landscape and district scale

At the landscape (e.g. watershed) level or district scale[1] mismatches between nutrient flows and land management become apparent. Examples are erosion and silting up of reservoirs and eutrophication of open waters. This scale also offers good opportunities for re-using nutrients, as most urbanization is within a specific district and previously underexploited resources (e.g. organic wastes, bio-slurry and sewage sludge) can be made available through re-cycling mechanisms. At this level of scale many institutions and organizations need to be involved, as what might be waste for one could be a valuable input for another.

With changing climate, changes in regional nutrient requirements will be most remarkable where we alter cropping systems to accommodate shifts in ecozones or alter farming systems to capture new uses from existing systems (Brouder & Volenec, 2008).

National scale

Policies are developed at the national scale that can facilitate the use of nutrients. But fertilizer supply chains determine which fertilizers are available to farmers. Farmers in many countries in sub-Saharan Africa (SSA) are still using generic fertilizer recommendations that do not respect differences in nutrient requirements due to differences in soils and crop types. Generic fertilizer recommendations commonly result in sub-optimum fertilizer applications with low nutrient use efficiencies (and consequently relatively high losses). Linking policy makers with applied research institutes may help to increase nutrient use efficiencies, soil fertility and long-term productivity.

[1] We avoid using the word ‘region’ as this can suggest both a sub-national scale and a supra-national scale. What we mean here is the (administrative) division of a nation, referred to as a province or district.

Continental and global scale

As a result of globalization, nutrients are currently transported all over the world. The global fertilizer trade map (Figure 5) demonstrates the global 'dragging' of nutrients. Yet, these flows are mainly between America and Asia, and Africa is scarcely involved, except as extraction areas for P (Morocco and Togo).

Another phenomena operating at this scale is land acquisition by foreign investors in developing countries, further reducing access to fertile land. In 2009, 45 - 80 million hectares was under negotiation (70% of which was located in Africa). This will clearly lead to changes in global power relationships.

In conclusion, it is evident that processes at higher levels of scale have major consequences for those at lower levels. This implies that, to be truly effective, nutrient cycling mechanisms designed to improve soil fertility need to address several spatial scales and be aligned by various institutions.

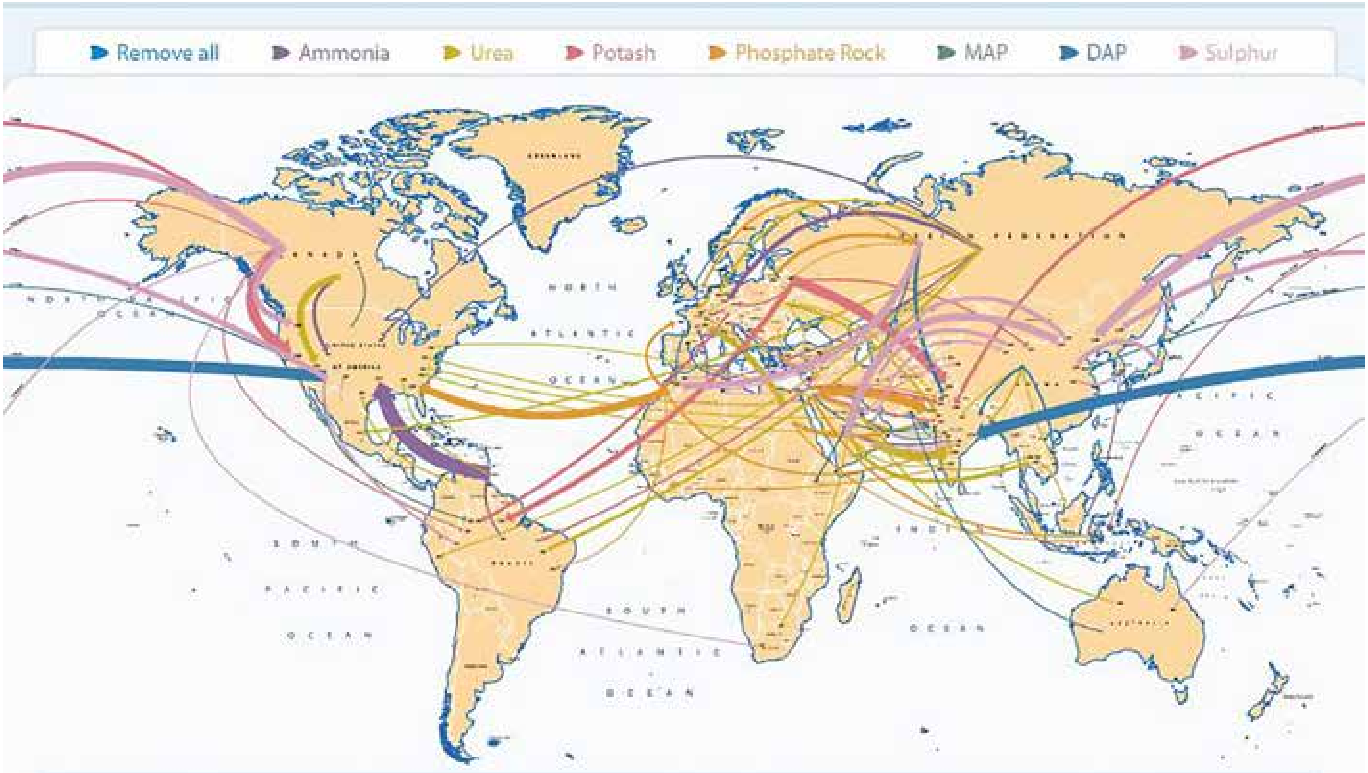


Figure 5. Global Fertilizer Trade Flow Map, representing the trade flows of fertilizers between the major producing and importing countries in the world, as well as production and consumption data. Source: ICIS (www.icis.com; October 2013).

4. Integrating the approaches: the Fertile Grounds Initiative

The interventions shown in Figure 3 may alleviate low soil fertility levels to a certain extent, but they will not solve the problem of disconnected nutrient flows and the discrepancy between approaches by the ‘organic’ world and the ‘mineral’ world. This is why additional action is required that will enable farmers in areas prone to nutrient deficiency in developing countries to improve their low soil fertility levels by optimizing and redistributing locally available resources, supplemented with external inputs. For farmers in resource-poor conditions increasing nutrient use efficiency is an effective way to increase farm productivity. As mentioned earlier, nutrient use efficiencies at the field and farm scales can only increase if there is better use and distribution of available nutrient sources. This understanding is fundamental to the Fertile Grounds Initiative (FGI).

The main aim of the FGI is to bring together organic and mineral nutrient flows to increase nutrient availability, efficiency and value, to increase economic activities based on the value chain, and to strengthen the ownership and independence of smallholders.

The Fertile Grounds Initiative consists of the following eight components:

1. Inventory of demand: farmers define their nutrient demand based on soil and crop specific fertilizer recommendations.

2. Inventory of potential supply: pools of organic matter within the sphere of activity are identified in terms of quality and quantity.

3. Product formulation and processing: sources of organic nutrients are converted into compost and supplemented with single or multiple compound mineral fertilizers to produce optimal compositions of nutrients as integrated fertilizer products.

4. Brokerage: supply and demand of nutrients are brought together and arrangements for trade are developed.

5. Trade and logistics: business case design, nutrient trade and transport.

6. Capacity building: farmers, extension workers, brokers and salesmen receive training in best practices for optimal nutrient management.

7. Institutional arrangements: cooperating with existing farmers’ organizations and/or setting up farmers’ cooperatives, defining the role of a nutrient bank, legal and institutional embedding, as well as government and policy support.

8. Creating an enabling environment for economic growth: mobilising support for market access, micro-credits, insurances, etc. for smallholders.

Nutrient supply and demand are brought together by brokerage, physical transport and the valorization of nutrients through a Nutrient Exchange Facility (NEF) platform (Figure 6). Nutrient brokerage is based on matching the amount and quality of supply with the nutrient demand of the farming system and the ambitions (i.e. targets) of the farmer.

Since organic nutrient sources are generally not readily

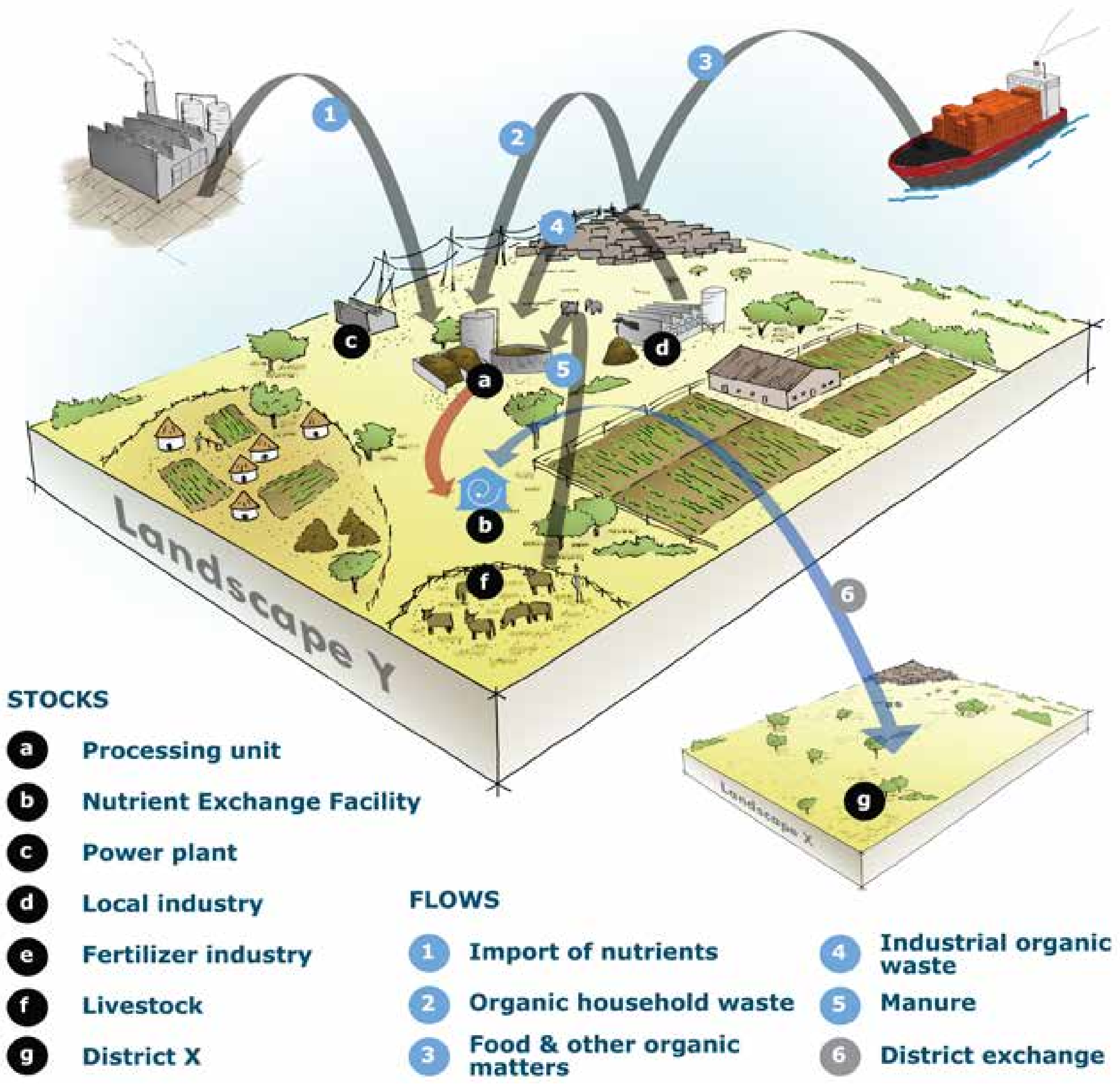


Figure 6. Elements of the proposed nutrient cycling mechanisms at the district level

applicable as fertilizer or readily available at the right time, collection, pre-treatment, composting, storage and transport will be integrated within the FGI to ensure a well-organized nutrient supply (Figure 7).

It therefore requires the concerted alignment of a variety of actors and stakeholders at various levels of scale (Box 5).

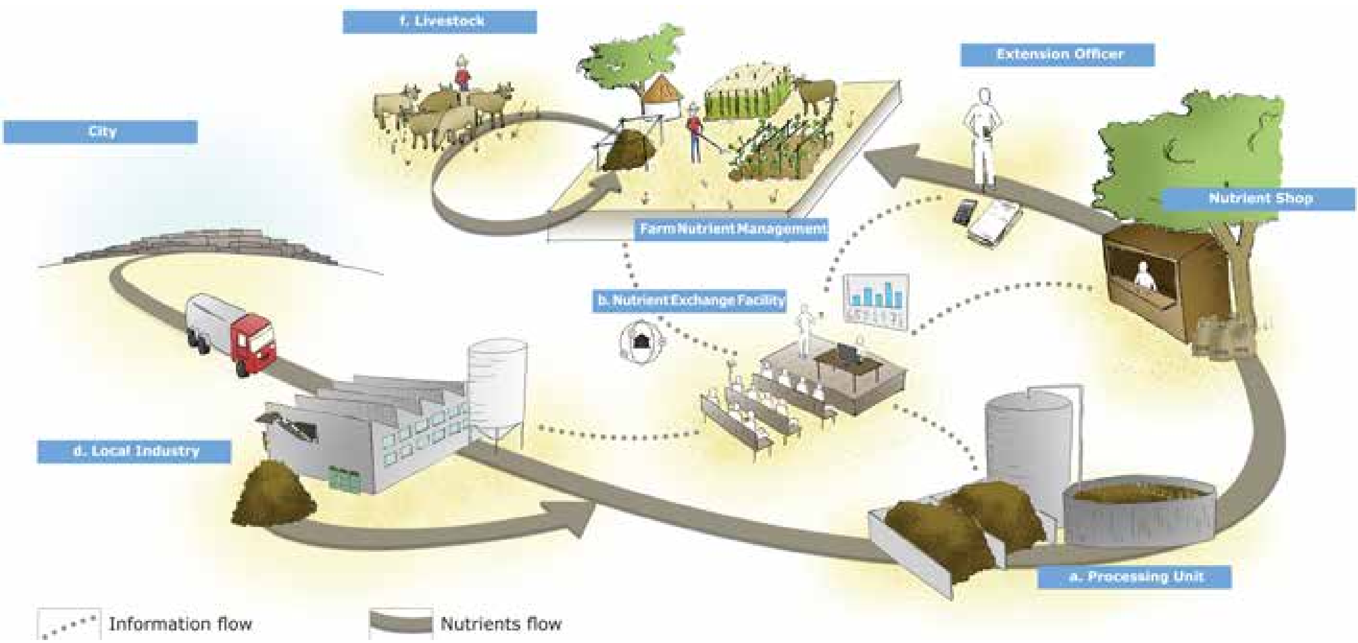


Figure 7. *Information and nutrient flows in the proposed nutrient cycling mechanism of the Fertile Ground Initiative*

Box 5. Education, capacity building, institutional change and an enabling environment

Change depends on the people who are willing to make it happen. Education, extension, capacity building and institutional linkages are all instrumental in the transition towards cyclical profitable food production systems. This system may be based on the Fertile Grounds Initiative, but it won't work without proper institutional linkages, effective policies, proper infrastructure, and market access.

5. The way forward

Globally, about €3 thousand million worth of soil nutrients are lost each year, thus severely frustrating the world's ability to meet growing demand for agricultural products. At the same time nutrient accumulation areas are struggling with the consequences of excess nutrients. This may seems to be a paradox, but it is in fact two sides of the same coin. Due to globalization, urbanization, population growth, changing diets, increasing costs of energy and climate change, meeting the challenge of resolving disconnected flows of nutrients – or to put it more positively: optimizing nutrient cycling mechanisms – is more urgent than ever. Since the entire nutrient cycle is inextricably interconnected at various levels of scales, there is no 'silver bullet'. Multiple approaches involving improved farming practices, local brokering of organic and mineral nutrient stocks and judicious imports of mineral fertilizers are what's needed. This is not a simple task because soils are still considered to be 'free goods' that can be degraded at will, but it is the only solution. The ingredients of the Fertile Grounds Initiative are not new. What's new is the integration of the previously separate worlds of supplies of inputs, local interventions and recycling of nutrients. We expect that this will increase the use of nutrients, their efficiency and, most importantly, volumes of agricultural produce. This is why the Fertile Grounds Initiative is a true implementation of the 'More with more, but smarter' philosophy which we all need to apply to increase food security.

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