Chapter 2
Beyond the Invisible: Finding the Social Relevance of Soil Nutrient Balances in Southern Mali

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Abstract The cotton-centered farming system of southern Mali has gained a reputation both as a paragon of successful, cash-crop led development and also as an example of serious soil nutrient depletion ("soil mining"). This chapter engages and critiques the social and developmental implications of the soil mining narrative and the language and methodology of soil nutrient balances that underpins it. By deploying the language of crisis in an "invisible" realm, soil scientists and development practitioners assert claims to control and knowledge of productive resources that would otherwise be the objects of intense social negotiation. The data-intensive calculation process also creates a false sense of precision about the "invisible" world of soil nutrients whose relationship to a social context is unknown or only implied. Examples from field work at the southern frontier of the cotton zone illustrate the partiality of the knowledge conveyed by nutrient balances and reveal the importance of multiple other "invisible" phenomena that were excluded from or could not be easily incorporated into the nutrient balance methodology. In the highly contested terrain of agro-pastoralism, migration, and mobility, these phenomena would include the constantly renegotiated access arrangements to land, labor, and livestock. The social relevance of nutrient balances can therefore only be improved by situating soil fertility within a broader context of environmental and livelihood factors, visible and invisible.

Keywords Soil nutrient balances • Agro-pastoralism • Farmers' knowledge • Livelihoods • Mali • Cotton

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L. German et al. (eds.), *Beyond the Biophysical: Knowledge, Culture, and Power in Agriculture and Natural Resource Management*,
DOI 10.1007/978-90-481-8826-0_2,

> How can I know what DT really thinks about his soil? I'm at his place nearly every day and the old man is happy to sit and swap stories about any topic under the moon well after evening prayer, poking at the smouldering fire. But it is as if the two worlds of my waking life are distinct, not only to him but to me: everyone knows I am here to learn about 'our way of life', especially all the networks of borrowing of labour and livestock, and so we talk about the weather, the crops and the [cotton] season and the cattle nearly no matter where we meet … but all these field measurements, these soil and plant samples seem almost *invisible* to someone like D, just my 'dirty little secret': They are constantly dismissed as "le travail des petits enfants", a game that must amuse dear Ziè and Maïga [the author and his Malian counterpart] as much as the kids who always join us, but not something that seems even remotely interesting to the men or their wives and therefore not even worthy of a joke or a sigh.
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> – Author's journal entry (May 16, 1996)

Introduction: What Soil Fertility Crisis?

Soil science and agronomy have improved understanding of soil fertility by quantifying and rendering "visible" the previously elusive world of soil nutrients as they flow or are deliberately transferred into and out of soils. But choosing to make certain phenomena "visible", through new techniques or research energy, implies that other components within the complex system of soils and agriculture are excluded or simplified by design, dismissed as irrelevant, or overlooked completely. There is nothing automatic about which phenomena are made or are left "invisible": such decisions are the result of the socio-political process by which scientific problems are identified as "do-able". This chapter explores how soil nutrient balances present a particular version of the "sustainability" of soil management practices, and the implications of privileging the biophysical world of soil nutrients over those aspects of soil fertility that are kept "invisible" within nutrient balance calculations. To do so it revisits case study material gathered during the year (1996–1997) that the author spent in a southern Malian community studying agro-pastoral livelihoods, interhousehold exchanges relating to livestock and land management, and their implications for soil fertility.

The soils of southern Mali in the mid-1990s played an important role (for Malian and international researchers) in presenting an apparently looming crisis of "soil nutrient mining": the unsustainable depletion of African soil fertility. Cotton production was booming and cash-crop led development was expanding in Mali beyond its historic home, making cotton the "success story of agricultural and rural development in Mali" (Bingen 1998, p. 271). But critics of this cotton-led development provided compelling, biophysical evidence that its prosperity was built on shaky foundations. Soil nutrient balances, calculated from the total inputs and outputs of both farmer-managed and natural biophysical processes, showed that despite its economic success, Mali's cotton zone as a whole was actually running a substantial deficit of crucial nutrients (van der Pol 1992). Similar, contemporary efforts to quantify the flows of nutrients into and out of African farming systems at the local, regional, and continental levels presented equally gloomy evidence of unsustainable exploitation of African soils (c.f. most notably Stoorvogel and Smaling 1990; Smaling 1993). Such balances are typically derived from data collected in farm or village-level case study areas (Kanté 2001; Smaling 1993; van der Pol 1992; Pieri 1992), reporting nutrient losses that range from just a few kilograms (of nitrogen, for example) per hectare to over a hundred kilograms per hectare. Such analyses have continued to be refined since that time with increasingly sophisticated models, which have attempted to incorporate not only better understanding of biophysical parameters but also to acknowledge the social complexity of agricultural systems (e.g. Rowe et al. 2006).

Soil nutrient studies bolstered the image that agriculture in most developing regions relies heavily on unsustainable "soil mining" practices. This literature forms, in the sense that the term was used by Roe (1991), a powerful development "narrative" that persuasively unites and explains various environmental degradation phenomena using seemingly exhaustive budgets of nutrient inputs and outputs for farming systems. Consequently many articles about African soils begin by citing statements like that of Sanchez et al. (1997, p. 1): "soil fertility depletion in smallholder farms is the fundamental biophysical root cause for declining per capita food production in sub-Saharan Africa". This oft-repeated line presents not only a correlation between negative nutrient balances, soil nutrient depletion, and declining per capita productivity, but also advances a claim that soil depletion and food insecurity are causally linked to declining soil fertility. These claims prioritize certain forms of knowledge – using the detailed analysis of nutrient flows to identify sites of nutrient depletion, for one – and necessarily omit or neglect other forms of knowledge that might impact soil fertility change, crop productivity, or food security. Yet reviews of nutrient balance studies emphasize that rigorous outcomes can be assured by paying sufficient attention to the details of calculations within the balances, believing that social and other sources of complexity have now been mastered by the modeling exercise (Hartemink 2006; Sheldrick and Lingard 2004; Smaling et al. 2002).

There are, of course, numerous critics of nutrient balances and the soil mining narrative they appear to support. Biophysical critics point to the problems of extrapolating from plot-level to regional and continental scales (de Ridder et al. 2004) or the heavy use of regression equations whose validity has still not been tested against empirical measures of actual losses (Færge and Magid 2004). Others bemoan the frequency with which a nutrient budget's quantification of an otherwise complex soil fertility problem is presented as a single, elegant number out of context, divorced from all the uncertainties, parameters, and errors that led to that number (Vanlauwe and Giller 2006; Kanté 2001). Social scientific critiques point out that most nutrient balances fail to account for the diversity of smallholder practices or the myriad ecosystem interactions on typical farms (Scoones 2001; Hilhorst et al. 2000). As a result, nutrient balances are often shown to be of limited social relevance in explaining the complexity of food insecurity and agricultural resilience actually lived by African smallholders (Ramisch 2005; Mortimore and Adams 2001; Mazzucato and Niemeijer 2001; Scoones and Toulmin 1998).

This chapter suggests ways in which the social relevance of nutrient balances can be improved, by situating soil fertility within a broader context of environmental and livelihood factors, visible and invisible. Otherwise, as is the case now, nutrient balances are essentially used as descriptive tools, either to depict the apparent severity of a "soil mining" crisis (Smaling et al. 2002; Gruhn et al. 2000) or to suggest the scale with which this crisis must be resolved through the necessary application of external inputs (Sheldrick and Lingard 2004; Sanchez et al. 1997). This is particularly relevant in the current context of major initiatives, like the Alliance for a Green Revolution for Africa (agra-alliance.org) or the UN Millennium Project, which still rely heavily on a fundamentally biophysical conceptualization and analysis of soil fertility.

We begin with the theory and practice of nutrient budgets as a background to how soil science has constructed and claimed rights over the interpretation of certain "invisible" aspects of the soil. This is followed by a brief overview of the research setting as a context for the methods and the data employed. The heart of the chapter then discusses the visible and invisible aspects of soil fertility knowledge with implications for nutrient balance calculations and illustrates social dimensions of soil fertility that remain "invisible" within, or entirely outside of, the conventional soil science approaches. It concludes with suggestions on how best to reconcile or incorporate the visible and invisible realms.

Making the Invisible Visible

The Theory and Practice of Nutrient Balances

Most of the nutrient balance work on West African and sub-Saharan farming systems has used the model developed by Stoorvogel and Smaling (1990). This model determines net surpluses or deficits of nutrients by measuring and summing all of the "imports" and "exports" of resources from a given plot.[1] This accounting model has obvious parallels with economics, which are invoked by Sanchez et al. (1997, p. 11) who claim an "exact congruence" between the soil science and economic concepts of "capital stocks" and the comprehensive accounting of "service flows" (nutrient fluxes during the growing season).

Ideally the identification of negative nutrient balances should localize farming systems or cropping practices that are "at risk" or indeed already unsustainably in decline. The continental and national level nutrient balances for sub-Saharan Africa (Sheldrick and Lingard 2004; Henao and Baanante 1999; Stoorvogel and Smaling 1990) all deploy their data with an advocacy agenda. Within the economic conceptualization of soil fertility, it appears self-evident that if nutrient exports exceed inputs there will be negative consequences for

[1]A list of flows is discussed below in Table 2.3.

current and future agricultural productivity in the same way that running a budget deficit must negatively impact on the finances of a firm or a nation. African farming systems are observed to be functioning at low levels of productivity, or are suffering declining yields, and the nutrient budgets further demonstrate that these systems are functioning in states of constant nutrient deficits (Henao and Baanante 2006; Pieri 1992).

Knowing the scale of the soil fertility reserves that the systems operate on, these models may estimate a time-frame beyond which present production will cease to be viable, having exhausted the soil resource (van der Pol 1992; Elwell and Stocking 1982). The conclusion is often that these alarming nutrient deficits must be redressed: through massive investments in inorganic fertilizers (World Bank 1996), through more efficient use of local resources, such as livestock (McIntire and Powell 1995), or through combining organic and inorganic approaches (Vanlauwe et al. 2006).

However, for reasons that are explored below, nutrient deficits do not in fact relate strongly either to agronomic productivity or to soil fertility status. Given such weak relationships, attempts to relate negative nutrient balances to food security (as done by UN Millennium Project 2005 or Henao and Baanante 1999) are problematic. It is worth noting that van der Pol (1992), the principle critic of Mali's "unsustainable" cotton sector, points to no current productivity crisis but only the likely threat of a future one. Mali's total cotton production increased through the 1980s and 1990s but expansion of the cultivated area was responsible for roughly 80% of these increases versus 20% accountable to fertilizer use (Berckmoes et al. 1990; Moseley 2005). As we shall see below, the relationship between area expansion (extensification) and input use (intensification) is socially complex with ambiguous impacts on nutrient balances, but these findings led van der Pol to state: "such developments increase the risk of land degradation due to nutrient depletion" (1992, p. 11), representing "a loan [taken] on future production capacity" (1992, p. 23). The much-cited finding from this study was that if these soil nutrients were to be replaced with inorganic fertilizers (the only way they could be given economic value) such an investment would cost 40% of the total income that was then being generated by cotton farming (1992, p. 23).

At the same time, van der Pol was careful to note that a negative balance is "not an automatic recommendation for additional fertilizer" (1992, p. 19). Local crop varieties might not be able to take up increased fertilizer applications, but to the extent that they could, increased yields would in turn increase extraction of soil nutrients. Fertilizer not taken up by crops would likely increase losses to leaching and volatilization. As a result he concludes that "[n]utrient balances cannot be translated directly into practical solutions. Nevertheless, they may constitute an important diagnostic tool, with the power to demystify the consequences of farming for soils, by describing them in a transparent manner" (van der Pol 1992, p. 20). While it is arguable that nothing is actually "demystified" if neither food insecurity nor low per capita agricultural productivity can be meaningfully explained by negative nutrient balances, this has not impeded the drive to make the "soil nutrient mining" crisis visible.

Presenting a Soil Fertility Crisis as a "Do-Able" Problem

The international and national soil and agricultural research organizations that have promoted nutrient cycle and farming system modeling have mobilized support for the creation of a set of clear and fundamentally technical explanations of smallholder agricultural processes. Casting light upon the mechanisms operating within the previously impenetrable realm of soil fertility's organic and mineral processes creates a complex array of new questions that all demand answers, and which must come predominantly from within the biophysical sciences: the nature and (re)formation of soil organic matter, the scale of nutrient transfers within and between (among others) soils and fertilizers (organic and inorganic), crops and their residues, to name just a few (Vanlauwe et al. 2006).

Powerful enough technical tools to support nutrient balance calculations began to come together in the early 1990s: analytic techniques of soil science, but particularly improved computing power and graphical mapping techniques. As Fujimura (1987) notes, however, new technologies alone are not enough to make a problem attractive enough for scientists to consider it "do-able". This process requires the articulation of a clear and pressing problem and necessitates building the capacity and the support of larger networks of actors from the "laboratory" (research institution) level up through the broader, social world of scientific communities, civil society, and policy makers.

Latour (2001) describes such a process when considering the "Pasteur-isation" of France. For Latour, Pasteur's success lay in identifying and promoting the role of invisible "microbes" as the actors behind seemingly unpredictable disease phenomena in the rural world. The "creation" of microbes as a concept – but also their literal culturing from spores in the laboratory setting – gave Pasteur the power to "translate" the previously disparate interests, knowledges, and disease vocabularies of farmers and veterinarians into the common language of a new, laboratory-based science. While this translation did hold a certain power – based on rendering visible for the first time the putative actors behind the most pernicious diseases of rural France – the knowledges and language of these different actors could nonetheless have coexisted without obvious hierarchy, each explaining different components of the world of rural diseases in ways potentially appropriate to the different actors. However, the power of the laboratory was assured when Pasteur was able to deploy the knowledge of microbes to visibly create and control diseases such as anthrax or chicken cholera that had previously eluded effective control by farmers or veterinarians.

A similar process explains how the soil fertility "crisis" in Sub-Saharan Africa was made "visible" by two continent-wide analyses of nutrient depletion (Stoorvogel and Smaling 1990) and land degradation (Oldeman et al. 1991). These studies were heavily cited as national and international actors built the case for "soil fertility" as a "do-able" challenge and helped unite two previously distinct narratives about African soils that had endured since colonial times. On the one hand, the "food-gap" narrative uses scenario models to contrast present trends of consumption based on population, economic, and agricultural production growth to show the future likelihood (taken as inevitability) of significant food deficits. The projections are used to justify further research into improved agricultural productivity per capita or per unit area to avoid this "gap" (Pinstrup-Andersen et al. 1999). On the other hand, the "poverty-degradation" narrative describes a negative, self-reinforcing "nexus" of population growth, poverty, and environmental degradation (Cleaver and Shreiber 1994). The growth rate of Africa's population is here not only leading towards an eventual food gap, but also the driving force behind shortened agricultural fallows, expansion of farming into "marginal areas", which will leave "its agricultural land … increasingly degraded" (Henao and Baanante 1999, p. 1). Together, such ideas reached their greatest expression in the World Bank's 1996 proposal for a Soil Fertility Initiative (SFI) in Africa: "Without restoration of soil fertility, Africa faces the prospect of serious food imbalances and widespread malnutrition and likelihood of eventual famine" (World Bank 1996, p. 1).

Situating the Research

Location and Farming Systems

Lanfiéla was selected as a representative agro-pastoral community of southern Mali for an in-depth study of farmer-herder relations and agroecology. The study area included 89 households and close to 1,500 individuals. A 50% sample was selected (44 households), stratified by the different ethnic sub-regions (Bambara, Minianka, or Fulani) and on the basis of equipment ownership and use (Ramisch 2005). In this chapter, respondents are referred to only by their two- or three-letter initials (e.g. "DT", "BST", etc.).

Cotton was first grown as a cash crop by prominent village families in the early 1960s. The parastatal Compagnie Malienne de Développement des Textiles (CMDT), which organizes input and output supply chains for cotton, expanded its presence in Lanfiéla in the late 1980s in recognition of the crop's growing importance in the sub-humid regions bordering Côte d'Ivoire. In communities such as Lanfiéla, cotton was incorporated into the farming system by increased use of animal draft power (for ploughing, weeding, and drawing carts). Since livestock ownership is far from universal, inter- and intrahousehold exchanges of ploughs, carts, and manure are prevalent within these communities.

In the village and hamlet, the cotton-maize rotation received the bulk of organic and inorganic inputs. Maize-pearl millet intercrops were often interplanted with cowpea or sown in rotation with groundnuts if they did not receive manure inputs. The Fulani households were distinct from the other communities with significantly larger cattle herds (30–300) and smaller cultivated areas, planted largely with pure stands of maize or pearl millet. Since few planted cotton, their access to inorganic inputs was negligible.

Households negotiated with each other year-round to secure access to a range of key resources (Ramisch 1999b, 2005). The exchanges with greatest impact on soil fertility were those made in the dry season to obtain either manure or the means to transport it to household fields. Most documented exchanges were made between members of the same sub-region, although a few took place between ethnic communities. Wet season exchanges concentrated on obtaining ploughs for land preparation or for weeding. Because households negotiated access to equipment that they themselves did not own, the use of animal draft power for cultivation, weeding, and transportation was much greater than the relatively low ownership of ploughs (61%) or carts (25%) would suggest.

Methods and Data Employed

The case study material derives from ethnographic, participant observation of agro-pastoral life and iterative, semi-structured interviews, conducted by the author and a Bambara-speaking assistant over the year 1996–1997. Our work was affiliated with Mali's national agricultural research organization through the Sikasso-based Equipe Systèmes de Production et Gestion des Ressources Naturelles (ESPGRN). Besides the village-based components, data were collected from interviews with Malian and international research scientists.

The research relied on several theoretical strands that were crucial to framing the original research questions of the author's doctoral work in "human ecology", at the intersection of the social and natural sciences. These strands were woven together by the "grounded theory" approach (Glaser and Strauss 1967): an inductive, empirically-driven, and predominantly qualitative methodology that simultaneously proposes and tests its emerging theories. On the one hand, political ecology questions, in the tradition of Blaikie and Brookfield (1987), considered natural resource management within Lanfiéla's historical context of social and political opportunities and constraints. I wanted to disaggregate these contexts to see how they operated at the level of individual actors or groups of actors (Long and Long 1992). On the other hand, the agroecological dimensions of the research concentrated on assessing the nutrient balance impacts of different individual and household practices. These calculations were derived from the NUTMON methodology (Smaling and Fresco 1993) and used participatory resource mapping techniques (Lightfoot et al. 1992) for visually depicting crop and soil management. The pioneering work in Mali on this methodology of mapping and balance calculation (Defoer et al. 1995) was subsequently codified as the "participatory learning and action research" (PLAR) approach for soil fertility (Defoer et al. 2000).

Nutrient Balances and Soil Chemistry

The overall balance of soil nutrients for the study area in 1996–1997 was a moderate deficit (–9.2 kg N ha^{-1}, +0.8 kg P ha^{-1}, –3.4 kg K ha^{-1})[2] (Ramisch 2005, p. 361). Balances calculated at the household level covered a considerable range (+59.8 to

[2] To simplify presentation, only nitrogen balances are used hereafter. Nitrogen is the most limiting nutrient in the region, and the balances of the other nutrients roughly follow the same trends as are seen with nitrogen.

–37.8 kg N ha^{-1}) and varied substantially as a function of households' agronomic decisions – such as the use of soil inputs or the reallocation of crop residues through grazing, transporting, or burning – since these are all explicitly incorporated in the calculation of the balances. However, there were no significant relationships at the household or the field level between the nitrogen balances and any measure of agricultural productivity, whether crop yields or overall biomass production (crop harvests and residues) in the 1996–1997 season or subsequent 1997–1998 season.

Soil chemical analysis in 60 plots gave equally complex, ambiguous findings. Soil nutrient contents did not significantly differ amongst cultivated land of various ages and fallows of 5–20 years (Ramisch 1999a, p. 14). However, soil N was significantly higher on some "home" fields compared to the "bush" and "fallow" fields in the same soil types (Ramisch 2005, p. 363–4). Soil C and organic matter content gave contradictory signals: higher in some older fallows, but otherwise not significantly different across soil types and uses. Other studies in Southern Mali have also found only weak or ambiguous relationships between nutrient balances, cultivation history, and soil fertility status (Benjaminsen et al. forthcoming; Moseley 2005; Kanté 2001).

Entering the Invisible Realm: Soil Fertility, Nutrient Balances, and Decision-Making

Knowing Soil Fertility: The Visible and the Invisible

In Southern Mali, farmers know their soils and their characters viscerally, not just by colour but by their feel and the ease with which they can be worked. Throughout Mali, Bambara speakers distinguish coarse textured *cencen* ("desert sand") from finer textured *bogo* ("mud") soils. They may be white (*-je*), black (*-fin*), or red (*-bilen*). The two local names apparently unique to the study area are also based on soils' visible characters. *Belencongo* ("the trampled soil") refers to the lateritic (*bele-*), white loam surrounding the village itself, once a wide, open plain, whose soils were too heavy and sticky to be cultivated on a large scale until the advent of ox ploughs. The swampy, rice-growing soils are named *nanga bogo* ("the belly mud"), which links the soil's rich-smelling, fertility with the swelling belly of pregnancy.

Beyond these evocative names soil is also the meeting place of the visible and the invisible realm, not just for Malian farmers but for soil scientists. Table 2.1 provides a schema for organizing knowledge for a given group of actors (e.g. local communities or soil scientists) based on both the ease with which phenomena can be observed and as a function of their perceived importance. The harder phenomena are to observe, the more likely that the knowledge about them is more locally held or site specific, and consequently more likely to be disputed or to differ with the knowledge of others, even from within the same group of actors. Scholars of ethnobiology (Bentley and Rodriguez 2001) have used this typology to show that for

Table 2.1 A typology of knowledge for visible and invisible phenomena (Adapted from Bentley and Rodriguez (2001), p. 288 and Bentley and Baker (2005), p. 59)

	Not of perceived importance	Of perceived importance
Easy to observe (more widely held, agreed upon knowledge)	Shallow knowledge ("trivia")	Deep knowledge (complex, widely held or consensual knowledges)
Difficult to observe (more variable, disagreed knowledge)	Disputed, partial, or "erroneous" knowledges	Complex, very variable (site-specific or contested) knowledges
	"Absent" knowledge(s)?	

"important" phenomena, such as the ecology of crop pests, local knowledges and the knowledge of scientist outsiders are most likely to agree on the most easily observed elements (e.g. the visible parts of a pest's life cycle). For harder to observe phenomena, these knowledges are more likely to diverge, each providing frequently very precise and detailed but different explanations, for example, for dormant or migratory pests' behaviors.

In Lanfiéla, respondents made it clear that their knowledge about how to improve crop yields through the use of animal manures, household wastes, and crop residue management constituted both "important" subjects and ones that were predominantly "easy" to observe. Yet site-specific elements, or knowledge arising from personal or family experience, added complexity to even these apparently easily observed practices. For example, many respondents related that ever since their ancestors (of the last century) observed the improved yields on fields where cattle herds had been corralled, manure was known to be valuable but within limits. A middle-aged male respondent voiced the common reservation that "the manure from the large [Fulani] herds that graze in the bush – that is a mixed blessing since you know that the next season you will be busy weeding all those bush seedlings out of your field." The dry season camping of transhumant Fulani and their herds on the cleared village fields was certainly the most visible agro-pastoral arrangement but knowledge about managing such exchanges was monopolized by the most senior and socially influential village households whose fields all had wells where the Fulani would water their calves and draw household water.

For a given actor, or set of actors, the ability and interest invested in observing, developing, or applying knowledge is clearly going to influence and be influenced by the perceived importance, as suggested in Table 2.1. But perceptions of importance are themselves going to be "situated", to use Haraway's term (1991), in a context of an actor's economic and political ability to make use of a resource. Knowledge about the worth and use of the piles (*ton*) of household waste, for example, ranged from the dismissive to the detailed. In general, throughout southern Mali, farmers believe that household waste, composted plant material (such as the harvested residual stems, hay, and stover of various crops), and livestock manure are all equivalent in their fertilizing value, all being described as *nogo* ("manure").

Some households in the study area indeed invested a great deal of energy in treating their *nogoton* as a resource: separating types of "wastes" (food, animal or chicken dung, crop residues, etc.) and managing them to varying degrees (e.g. by digging a pit for them, heaping or turning the waste pile, or covering wastes with leaves). Others treated these wastes purely as "trash" (*nyama* or literally "nonsense") and professed no particular knowledge or interest in them except as a consequence of more or less fastidious cleaning of the home compound area and as a burden that needed occasionally to be removed.

That some households greatly value these household waste piles, and others want only to be rid of them fuelled a healthy trade in interhousehold manure exchange (c.f. Ramisch 1999b, 2005). The inequality that fuels this trade shapes the relative value of knowledge about household wastes and their management. Households without enough labor to move their own waste pile, or who lacked the equipment to do so (e.g. donkey carts), were less likely to invest energy in knowing or managing their waste piles. But just because the knowledge is considered "trivial" does not mean the resource itself is not valued. The most common dry season arrangement was for households borrowing a donkey cart to "pay" half of the transported manure to the cart owner's fields. Cart owners aggressively sought out households that had manure or household wastes to transport, to profit from such a deal. Similarly, households with large *nyamaton* often viewed this arrangement as a way to clear these piles, preferring to use part of this "waste" supply as payment in lieu of scarce cash. Unsurprisingly, the donkey cart was the most coveted asset for many of the smaller, labor-poor households. As one such farmer complained, "Without a cart, the work is harder, everyone is trying to exploit you, and the work is never finished on time!"

Staking a Claim on the Invisible: The Logic of Soil Nutrient Balances

The primary interest of the agroecological research in Lanfiéla was to focus on the lower left quadrant of Table 2.1: the apparently "invisible" realm of soil nutrient cycling that local communities cannot easily observe and, as a consequence, might be undervaluing. Comprehensive nutrient balances were calculated based on values originating from participatory mapping exercises conducted with each household: detailed diagrams of crop and soil management that visually presented the inputs and outputs from every plot and field (c.f. Defoer et al. 2000). The values generated in these exercises were then corroborated by field measurements (e.g. of organic inputs transported to fields or of residues grazed) and validation of harvested or transported amounts.

As Table 2.2 shows, the nutrient flows managed by farmers are predominantly "directly visible". However, the PLAR methodology employed assumes that farmers' management can be improved not only by having their own decisions' impacts made visible in the diagramming process, but also by including the flows that are

Table 2.2 The (in)visibility of nutrient flows influencing soil fertility (Derived from Smaling and Fresco 1993)

	Minor impact on agricultural production	Major impact on agricultural production
Directly visible	Crop residue removals (grazing, stocking, burning)	Inorganic fertilizer, manure, and household wastes (transported), crop rotation, intercropping
Indirectly visible	Legume nitrogen-fixation	Manure from grazing or corralled animals, soil erosion
Invisible	Sedimentation, dust inputs, parent material weathering	Leaching, gaseous losses

only "indirectly visible" (such as the contributions of soil erosion or symbiotic nitrogen fixation) or "invisible" (such as leaching and gaseous losses) (Defoer 2002; Smaling et al. 2002).

There is a powerful and absorbing logic behind these calculations: to accurately quantify crop yields, inorganic or organic inputs, or the fate of crop residues can easily become an all-consuming task given the scale and complexity of the data required to calculate a full balance. The data-intensive demands of nutrient budgeting commits a research team to a treadmill of obligations. The dedication to making each household's agricultural balance sheet of all the requisite variables "visible" (and within an acceptable margin of error) can easily eclipse all other concerns. As I remarked in field notes at the height of the cotton harvest (December 16, 2006), "this constant chase – learning today, while taking measures in MT's field that DS was also harvesting! – becomes so exhausting. It is easy to see why [the research team that had pioneered this technique further north in the cotton zone] had time for nothing else!" The very thorough and seemingly exhaustive list of variables can give the comforting sense that all the biophysical factors are and can be measured. At the same time, the fact that most of the directly visible flows can be decomposed into components that differ based on social groups or socially influenced activities can also provide the apparent sense that the nutrient balance model is sensitive to and can incorporate not just the biophysical but the social dimensions of soil fertility management.

Both the availability and the reliability of such data can be quite problematic, since units of measure are not necessarily standard between (or even within) households, and many of the resource flows are subject to considerable variation in both space and time. Table 2.3 shows that even in a carefully managed data collection exercise many of the potentially largest flows of nutrients in and out of a household's farming system are subject to multiple sources of uncertainty, only some of which can be seen or realistically compensated for. Even conducting regular, weekly interviews and using households' own record keeping would not eliminate the need to rely on recalled or estimated values. Many of the *in situ* observations, either of the fate of crop residues or the application of organic matter, rely on highly subjective assessments of proportions and resource quality. Erosion, another, potentially

Table 2.3 The magnitude, availability, and reliability of data collected for the nutrient balance calculations in Lanfiéla

Variable	Magnitude (kg ha^{-1})	Data Availability		Other considerations?
		Visible?	Reliable?	
OUT1: harvested crop	−27.6 (16–60)	Yes	***	Harvests were spread over extended periods and transported or stored in diverse manners
OUT2: crop residues	−15.7 (0–38)	Yes	**	Ratio of the "available" crop residues to the harvested crop was not necessarily a constant, needed validation
– OUT2a: stocked residues	−1.2 (0–10)	Yes	**	Residues stocked as animal feed were reasonably easily recalled, but local measures are by volume, not (dry) weight
– OUT2b: composted residues	−1.4 (0–15)	Yes	**	Residues transported to compost pits were reasonably easily recalled but local measures are by volume, not (dry) weight
– OUT2c: burnt residues	−9.3 (0–22)	Partial	*	Quantified *in situ* after burning, impact subject to major variability (early vs. late burning, incorporated at ploughing, etc.)
– OUT2d: grazed residues	−3.7 (0–20)	Partial	*	Observations usually inferred only from herd size, time of grazing rather than direct measures of removal, tramping
OUT3: leaching	−16.3 (4–47)	No	*	Potentially major output but only estimated by a "transfer" function
OUT4: gaseous losses	−21.7 (10–55)	No	*	Potentially major output but only estimated by a "transfer" function
OUT5: erosion	9.2 (0–37)	Possibly	*	Difficult to quantify without dedicated resources
IN0: residues incorporated	+16.4 (1–56)	Partial	*	A residual calculation of "available residues" minus OUT2
IN1: inorganic fertilizer	+36.1 (0–114)	Yes	****	As a purchased input, quantities are easily known, but application methods (broadcasting, pocket planting, etc.) have important impacts on plant uptake, leaching, gaseous losses
IN2: organic fertilizer	+20.7 (0–209)	Yes	**	Quantities of transported material relatively easily known, although local measures are by volume, not (dry) weight; resource quality will be highly variable (household waste, compost, fresh vs. dried manure, etc.); manure from corralled herds harder to assess
IN3: atmospheric deposition	+8.5	No	*	Calculated by "transfer" function (flat rate for entire study site)
IN4: symbiotic fixation	+2.2 (0–11)	No	*	Calculated by "transfer" function

"Magnitude": The average value of the given flux in 1996–1997 calculated at the household level, with the maximum and minimum household values given in brackets below.
"Reliability": A qualitative assessment from most "****" to least "*" reliable as a function of potential errors in data collection, validity of measures, quality of secondary data, or relevance of the regression equations used in the "transfer functions".

important loss of nutrients is complicated and site-specific enough to merit an all-consuming study of its own and in even the best nutrient balance calculations is typically estimated from fairly rough field observations and comparison with the few local or regional studies (if they exist at all). Finally, it is worth noting that two of the largest probable losses of nutrients, through leaching or gaseous means, are not only invisible but can be estimated only on the basis of predictive equations (so-called "transfer" functions). These functions are derived from a relatively limited number of small-scale, soil science studies under controlled conditions but represent the most tangible claim that soil scientific knowledge makes upon the invisible realm (Færge and Magid 2004).

"We Don't See What You See": Farmers Assess the Nutrient Balances

As Table 2.3 shows, the more invisible, "biophysical" transfers were on average at least as large a removal of nutrients as that represented by the visible, harvested products. They were also large enough to account for the overall negative nitrogen balance of the sample, as well as the negative balances of many individual fields and households (Ramisch 1999a, p. 13). In their absence, balances calculated using only the visible components of the system (so called "management-only" or "partial balances") would likely be positive. This has been the case with "partial balances" calculated by other authors elsewhere in southern Mali (Kanté 2001; Defoer et al. 1995). The "full" balance of the soil scientist's knowledge is therefore directly at odds with the visible, "management-only" balance, with all the presumptions of greater authority and more comprehensive knowledge that the term "full" entails.

Respondents were often perplexed during the feedback sessions to see the fields and the systems that they felt were the most productive being portrayed by the mapping and nutrient balance exercises as running the largest deficits. This included not only the most heavily fertilized or manured cotton fields, but also fields that been recently cleared from fallow and not manured, on the assumption that they were still "inherently" fertile (something which does not show up as in "input" in Table 2.3). While the relationship between system inputs and outputs might have been clear-cut under the conditions of a managed agronomic trial, in the actual farms fertilizer or manure inputs were no guarantee of improved yields or of a positive nutrient balance at the end of the season. Examples from the studied households show that a well-fertilized cotton field, planted at an appropriate time and weeded regularly would indeed often yield so prolifically that the nutrient exports far exceeded even the abundant inputs that were also applied (presumably exploiting reserves of soil nutrients). Other cases of strong, negative nutrient deficits could be found amongst unfertilized, unmanured maize or millet fields, whose residues were burned, grazed, or otherwise removed after the harvest (outputs > meagre inputs). By contrast, positive nutrient balances were ironically most evident in situations where manure or inorganic fertilizer was applied, but where prolific weeds, pests, or other factors led to low crop yields and consequently low nutrient exports (inputs > miserable outputs). Only a few fields showed positive nitrogen balances for the supposed "best practices" of input use, residue re-incorporation, and above average crop yields.

This led to many respondents laughing off the "lessons" about sustainability that the nutrient balances were expected to provide. "You are focussing on the wrong things," said one farmer. The map had no way to depict what he perceived to be the important effects of intercropping maize, millet, and cowpea ("they all eat differently and they take turns growing with the rain"), as well as the residual effects of previous years' manuring, cotton fertilizer, and even the still-decomposing tree stumps from land clearance. Another comment suggests that the productivity of a given field would never relate back to the nutrient balance of a particular year and had to be understood more broadly:

> "I will get a lot of maize here for a lot reasons. It is not just the soil – this [village soil] was already old soil when I inherited it, after all – or whether we can afford to put fertilizer. If my sons are all here, we catch the rains and we will work the land well. If they are not, and I am old, or tired, or sick, the work will obviously not go well. And some people just have better luck than others. There are just a lot of reasons."

Which "Invisible" Realm? Soil Nutrients in a Social World

In effect, the participatory dialogue stemming from the nutrient balancing exercise revealed that while the nutrient balancing logic believed that we as researchers had cast light upon important but heretofore "invisible" phenomena, there were multiple dimensions of "soil fertility" (or even "agricultural sustainability") that were important to our respondents but had remained invisible. Respondents had made decisions, for example, about intensifying their agricultural production (through greater labor or input use on a fixed area), or increasing their production by expanding their cultivated areas (through greater labor use or investment in animal traction). The nutrient balances (either "full" or "partial") could allow some of the purely biophysical aspects of a single season's decisions to be modelled, but not in the "right" or "enough" detail to impress farmers or to convince them that the outcomes were useful for planning responses.

To be fair, agroecological researchers would also acknowledge that nutrient balances are only a "snap-shot" of a single season's practices (Defoer et al. 2000) and can depict "sustainability" or guide decision-making only in a context of existing soil nutrient reserves (Hartemink 2006). Individual researchers at ESPGRN would clarify, as one senior scientist did, that nutrient balances on their own "cannot – and never claim to – be used for [agronomic or land-use] planning at the farm level" (see also Vanlauwe and Giller 2006). However, the idea that negative balances represent a systematic withdrawal of nutrient "capital" that must be replaced underpinned researchers' statements that nutrient balance calculation nevertheless "allows farmers and researchers to locate and reflect upon their most unsustainable practices" (same ESPGRN scientist). The belief that "there are no historical examples of sustained agricultural development in areas with declining soil fertility" (van der Pol 1992, p. 20) was deeply entrenched and guided the application of the nutrient balancing methodology as a "learning tool".

The household-level factors that influence soil fertility shown in Table 2.4 can be contrasted with the presentation of nutrient-only factors shown in Table 2.2. "Visible" phenomena in Table 2.4 can all be observed directly in households' fields but only some of these are incorporated into the nutrient balance calculations, e.g. the direct measurement of certain crop husbandry and waste management practices such as input application or the fate of residues. Other important and "visible" phenomena with significant interhousehold variation are not included: the impacts of crop spacing and intercropping; the timing of planting, weeding, or harvests; or the impacts of crop varieties, weeds, crop pests, or diseases. Their impact is seen only in aggregate, in the overall harvest of crop or crop residues, and cannot be depicted or manipulated in the mapping.

Perhaps the most important "visible" factor, according to respondents, was rainfall – not just total precipitation but the timing, predictability, and spatial distribution of storms. "We are always chasing the rains", said one respondent, describing how most agricultural tasks like planting and weeding wait for and then must rapidly respond to rainfall. "Too little" or "too much" rain can make working the land difficult, or hamper the timely execution of tasks in ways that have major impacts on crop productivity. Rainfall (and temperature) would also significantly influence leaching and gaseous losses of nutrients in ways that the nutrient balances' "transfer functions" are only approximating: capturing such impacts would require sophisticated monitoring equipment far beyond the means of the methodology. At a more general level, most of the old farmers would dispute the claim of the soil scientists that crop yields (in terms of kilograms per hectare) have been declining, since the more important, visible trend in Lanfiéla was that of rainfall diminishing and becoming more erratic (cf. Pieri 1992 for similar observations across the Sahel): "In a good year, our land will do at least as well as when I was a boy. Last year (1995–96) we had enough rain, we planted on time, and there was enough [cotton] fertilizer for us apply. But that was a good year." (BDT)

Table 2.4 The (in)visibility of household-level factors influencing soil fertility

	Minimal intrahousehold variation	Major intrahousehold variation
Visible	Crop varieties; rainfall (onset, duration, frequency, quantities)	Crop husbandry (timing, spacing, weeding); pests, weeds and diseases; manure and household waste management
Invisible	Market prices; quality and variability of purchased inputs	Labor availability and bottlenecks (planting, weeding, harvest obligations; out-migration effects); intensification and extensification decisions; interseason and residual effects (manuring, fertilizer use, burning, land clearance); manuring and grazing arrangements; land tenure; market access

(Synthesis of factors reported by individual and group interviews, Lanfiéla 1996–1997)

The "invisible" factors in Table 2.4 are all factors that respondents used to justify or explain their decisions to intensify or extensify their agricultural production, and were cited as having had an impact on their perceptions of their soils' fertility. All these factors lie entirely outside the consideration of the nutrient budgets and would have to be gathered through data collection off-farm (e.g. market prices or the quality of inputs), social analysis (e.g. land tenure, labor, manuring or grazing arrangements), or longer term household analysis (e.g. interseason and residual effects of land-use, out-migration). Three case studies from Lanfiéla elaborate on the ways in which factors from the lower right corner of Table 2.4 can put nutrient balances in a broader, social context, considering time, livelihood, and community dimensions.

Case 1. Cotton or Côte d'Ivoire?

BST's household was one of only four in the sample that relied purely on hoe cultivation, which would place this household in Class "D", the lowest, "poorest" rank within the CMDT's wealth ranking. However, their cotton and maize yields in 1996 were both above the village average (1,573 and 1,335 kg ha^{-1} respectively). The head of the household (BST) was justifiably proud that their total cotton harvest put them in the top 40% of income earners, ahead of bigger and better-equipped, plough-owning families. "When my sons were younger we used to hire a plough from [a neighbour], but now we have enough labour to manage on our own."

The use of this labor is interesting. BST and his four sons worked the land during the planting and weeding part of the year. The two women later helped with the harvest, while two younger children did not work in the fields at all. The eldest son spent a good part of the year in Côte d'Ivoire, doing odd jobs and construction work, but would return for each agricultural season. It was expected that, within a few years, his younger brothers would follow this example, which had been set by BST himself a generation earlier when he was still young and unmarried. "You had to choose between working cotton and Côte d'Ivoire, but when you are young it is no choice at all. Cotton is your father's [money] and you will always come back to it some day. But in Côte d'Ivoire you can make money of your own, send it home, and make your own life." The proximity of Lanfiéla to Côte d'Ivoire means that at least half the total population may be absent at any time, involved in migrant labor south of the border. Resident villagers rather pragmatically also justified out-migration as valuable for "reducing the number of mouths to feed" at home. However, many young migrants would be expected to return home to work during the peak agricultural seasons.

This household's dedication of energy to hoe cultivation yielded an impressive cotton harvest in 1996, but was not able to apply significant amounts of organic or inorganic inputs. As a result, the household nutrient balance was –29.1 kg N ha^{-1} on nearly 5 ha of cultivated land, which ranked the household in the bottom 10% of the sample's household balances. The eldest son actually did not find this surprising, "Of course we will use our soil: what else do we have here? But it is not as if the money from that cotton is going nowhere, is it?" Many households would describe a cycle of nutrient depletion that would be used to finance new livelihood opportunities, followed by fallowing or later reinvestment in their land (c.f. Scoones 2001). In this household's case, the availability of young male labor during the agricultural season ensured good food and cash crop yields without (for the moment) the need for costly manure or fertilizer expenditures. Out-migration was also reducing the household's costs in Lanfiéla while creating new, livelihood opportunities in Côte d'Ivoire for the younger sons in the near future. Finally, remittances and cotton income were being used to finance two weddings in 1998, representing serious, household investments in a future back in Lanfiéla.

Case 2. Nutrient Balances in Space and Time

DT's household is much older, larger, and more complex than BST's, and illustrates the challenges of accounting for area expansion and crop rotations. The land that he had inherited from his father, which included both a "home" field adjacent to their compound in the village and a smaller "bush" field nearly 2 km away, had been split with two other brothers. These three households continued to pool their labor and the use of their ox ploughs for major agricultural tasks. Many of DT's sons and daughters had migrated to town or to Côte d'Ivoire but with two of the sons returning in 1996, the household proper included 6 men and women actively working on the farm all year long and a further 19 women and children who contributed during weeding and harvest. One of the main projects occupying the household that year was the expansion of its 1.5 ha "bush" field: many trees were felled and burned through the dry season and over 4 ha was initially ploughed. However, this area proved too ambitious for the available labor, even with the two, returned sons and the labor of brothers and nephews. Ultimately only 3.8 ha of the bush field was planted with cotton, millet, and groundnut, and – as that freshly cleared field filled with weeds – barely half that area (2.5 ha) was actually harvested by the end of the year.

Such a scenario illustrates the complexity of agricultural tasks as they are truly executed in a world of unfolding labor bottlenecks, as well as the problems facing a nutrient balance calculation. The decision to "sacrifice" the weediest parts of the farm in the latter part of the rainy season was pragmatic, but leaves social and biophysical justifications for dividing the calculated –38.1 kg N deficit of the "bush" field, for example, against the 2.5 ha harvested (–15.2 kg N ha^{-1}), the 4 ha ploughed (–9.5 kg N ha^{-1}), or the 3.8 ha planted (–10.0 kg N ha^{-1}). Furthermore, whatever nutrient deficit is calculated for 1996–1997 needs to be put in the context of the past and future managements. The typical rotation of maize (fertilized and manured) following cotton is often sufficient to compensate for the apparently large deficits of a cotton season in a given field (Ramisch 1999a, p. 20). In this particular case, DT explained that the "bush" field was still endowed with "energy, fresh from the [cleared] forest" (something the nutrient balance could not calculate) and therefore hadn't received as much mineral fertilizer as the older, "home" field. The household's cotton harvest in 1996 was its largest ever, even if the per hectare productivity of cotton on their land had declined.

The price of mineral fertilizers increased significantly in Mali in the mid-1980s, following the lifting of subsidies under the IMF-led structural adjustment programme. A common response countrywide was the substitution of increased area of cultivation for reduced fertilizer use (Benjaminsen 2001). DT's example suggests that while overall cotton output increased, any drop in per hectare productivity was more associated with the increased labor demands that went unmet on the larger area than to nutrient depletion or to having expanded cultivation onto "marginal" land.

The ability of households to extensify production in Lanfiéla is embedded with a number of "invisible" assumptions, such as land tenure, commodity prices, and the ability of a household to deploy labor or networks to respond. DT, commenting on the decision to expand the "bush" field:

> "That forest was never a place my father or his father farmed, it was a forest! And yes, the hamlet farmers might have one day farmed it but that is not my problem. With the price of cotton this good, it was worth all this work to clear the trees. By god it was work, but now we can use that field for whatever we choose."

This option is much less available further north in Mali's cotton zone, where the landscape is more fully covered by cultivation and forested fallows are scarce. Throughout Mali, land rights are usufruct[3] and available through negotiation with villages' founding lineages. This can add incentives for households with labor resources and/or good elite connections to maximize the area they cultivate, potentially by "claiming" or "borrowing" fallows from less advantaged households (cf. Moseley 2005, p. 50).

Case 3. Nutrient Flows as Social Flows

The third case (DD) involves the founding family of the Fulani settlement, which had the largest cattle herd in the area (343 head in early 1997). They also had a conspicuous abundance of manure produced both in wet season corrals in the uncultivated bush near the home compound, and dry season ones on the household's 5.88 ha crop land. Corralling the herd on the farmland was the preferred means of fertilizing but these branch enclosures were too massive to move often, leaving large parts of the crop land unmanured during the dry season. To fertilize these areas, and to clear out the wet season corrals, DD's household borrowed a cart every year to accelerate the burdensome task of applying (in 1997) 14.63 t of manure. An equal amount was given to the cart owner as payment for the loan of the cart, a "gift" that in 1997 conferred 190 kg N.

This arrangement was viewed as a bit of a prize for any cart owner in the village. Often, if the village chief or another elder's cart was used, it had served to maintain

[3] A household or individual only has the right to *use* the land (i.e. to cultivate it) and cannot buy or sell it. If cultivation ceases it reverts to the lineage and is available for someone else to exploit, so long as the lineage elders support that claim.

solidarity between the Fulawere settlement and the villagers. In 1997, however, the chosen cart owner was the recently arrived head-master of the village school, himself a sedentary Fulani with no animals. To many of the cart-owning villagers, this intraethnic deal seemed too cosy, a subtle rebuff for the previous season's exclusion of Fulani herds from watering at the newly finished village dam.

From the nutrient balancing standpoint, this household was doing extremely well, ending 1996 with a surplus of 59.8 kg N ha^{-1}. However, this did not translate into superior crop yields: weeds flourished as well as the millet and maize, whose yields only matched the area average. Part of this might be due to the dedication of most of the household labor to herd management rather than crop husbandry. From the family's own perspective, though, this was evidence that despite the heavy manure doses "the land grows tired": several years before, they had been selling part of their maize harvest, but could no longer afford to do so in 1995 or 1996. DD felt that inorganic fertilizers would help improve their yield but commented: "We don't grow cotton and so the CMDT has no time for us. We can't get their fertilizers or the [cotton harvest-based] credit to buy them." The strongly positive nutrient balances of these heavily manured fields supported the transfer of nutrients to elite villagers' lands but the exclusion of the Fulani households from the "development" afforded by cotton to the rest of the village was palpable.

Reconciling Invisible and Visible Perspectives: Implications for Research and Policy

Previous critiques of nutrient balances have warned that the data-intensive calculation process creates a false sense of precision about the "invisible" world of soil nutrients whose relationship to a social context is unknown or only implied (Mortimore and Adams 2001; Scoones 2001; Ramisch 1999a; Scoones and Toulmin 1998). The material presented in this chapter confirms the partiality of the knowledge conveyed by nutrient balances by revealing the importance of multiple other "invisible" phenomena that were excluded from or could not be easily incorporated into the nutrient balance methodology. Declining cotton yields (if such a trend was even visible, since overall production continued to grow) could not easily be attributed to soil factors when farmers themselves noted that declining or variable rainfall, or decisions about area expansion and labor bottlenecks were more visibly impinging on productivity. Households such as BST's or DT's who were shown to be running negative balances either believed this was a necessary, temporary measure to fuel other livelihood improvements, or considered that such deficits would be offset by future crop rotations or compensatory soil management. The snapshot of a given season's impacts was therefore easily dismissed as only part of a greater story about any particular household's agricultural or livelihood portfolio. Even positive nutrient balances, such as in DD's case, were no assurance of a "sustainable" system or of good yields given the social precariousness of the pastoral Fulani livelihoods within the cotton-dominated landscape.

To what extent should the factors displayed in Table 2.4 be included in biophysical analyses, such as nutrient balances? In a truly participatory and emancipatory science this question can only be answered by those who are going to use (or to further contribute to) the knowledge such biophysical analyses are intended to generate. In Lanfiéla, initially understood as an "agro-pastoral" community but clearly one where migration and return are even more central to many livelihoods, the factors outlined in Table 2.4 could serve as the basis of a broader set of indicators to describe agricultural or livelihood sustainability. In such a situation, nutrient balances and resource flow mapping might be useful for describing subcomponents of household farming systems, and could be used to compare the impacts of different management decisions by the same actor. With measures of soil nutrient status, balances could also contextualize trends of crop or soil performance (Moseley 2005; Benjaminsen 2001; Kanté 2001). But given the problematic nature of data collection and full balance calculation, it seems unwise to present data generated by nutrient balances to policy makers as conclusive evidence of a soil fertility "crisis" or to guide land-use planning questions, such as whether to continue expanding cotton areas, either locally or at more regional levels.

It is true that nutrient balancing methodologies and models have advanced considerably in the ten years since I first worked in southern Mali. The NUTMON methodology, for example, has evolved from a focus on farm-level nutrient management to a methodology now called "MonQi": a "multi-scale, multidisciplinary" monitoring and evaluation tool that considers not only soil nutrients but financial and "environmental" analyses of farm livelihoods (MonQi.org). Other, recent modeling efforts (e.g. Rowe et al. 2006) have also included livelihood components and labor submodels even while attempting to resolve uncertainties within the biophysical components. Such models bring ever greater data demands and still rely, as NUTMON or PLAR did, upon assumptions and simplifications of subcomponents that are outside of the focus of "visibility". The alternative approach is to restrict nutrient balance calculations to purely biophysical phenomena, tracking for example the nutrient demands and uptake of alley-cropped trees and maize (Radersma et al. 2004). While certainly of use to agronomists or plant breeders, choosing to treat soil fertility only in terms of mineral nutrients is unlikely either to interest farmers or policy-makers, or to lead to a broader understanding of the complex ecologies of agricultural landscapes.

The power of the nutrient mining narrative lies in appearing to make visible an explanatory mechanism for a broader crisis of food insecurity and rural poverty in Africa. The danger of this narrative lies in taking the nutrient flows it has made "visible" and letting them eclipse everything else: assuming, for example, that redressing soil nutrient imbalances is the "entry point" to boosting agricultural productivity and halving hunger by 2015 (UN Millennium Project 2005, p. 107). This case study does not dispute the existence of Africa's livelihood or environmental problems, but cautions that simply casting light upon a particular, biophysical component of soil fertility does not necessarily reveal the true nature of something so complex. Each nutrient balance "snapshot" of a household's farming system is already only a partial reflection of that system's sustainability with social parameters and forces essentially excluded from the balance calculation. Scaling up or aggregating such snapshots to the community, regional, or (inter)national level will only further distort any interpretation of what is made "visible" and what is not in any given analysis.

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Beyond the Biophysical
Knowledge, Culture, and Power in Agriculture and Natural Resource Management
German, L.; Ramisch, J.J.; Verma, R. (Eds.)
2010, XVIII, 301 p., Hardcover
ISBN: 978-90-481-8825-3