Figuring rural development : concepts and cases of land use, sustainability and integrative indicators

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Material Flow Accounting of Rural Communities: Principles and Outcomes in South East Asia

Abstract

The chapter develops a system of local Material Flow Analysis that links material flows to issues of land use transition, globalisation and food security. This system (rMFA) is then applied to villages in Vietnam, the Philippines and Laos. The rMFA shows that these villages greatly differ in terms of these indicators, and with that, in terms of risks and future-oriented policies, issues that remain hidden in standard MFA indicators, as illustrated by an MFA application in India. The methodological conclusion is that rMFA offers a good tool for theory-connected insights and cross-country comparisons.

4.1   Introduction

Under the pressures of population growth and globalization, agriculture in South-East Asia is undergoing many processes of change, such as, for example, increasing extraction of natural resources, intensified use of capital and labour inputs and the development of factory farming. These changes often go together with environmental imbalances that express themselves as pollution, soil degradation or resource depletion.

Material Flow Analysis (MFA) is a system approach that aims to elucidate human-environmental relations by focusing on the physical dimension of the economy. It studies the material basis of a social system (e.g. a society, a region or a village) by accounting for the import, extraction, transformation, waste, emission and export of materials. Due to its broad and systematic character, MFA may not be the most efficient tool to rapidly pinpoint specific problems in specific places. For the same reason, however, MFA may well be effectively used to describe basic processes in the human-environment metabolism and to compare economies (at any geographical scale) with each other via approaches such as the use of aggregated indicators. As discussed in the coming sections, such indicators are in fact in broad use already.

MFA has been widely used at the national level, and Eurostat (2001) has published a standardization for national-level MFAs. However, in this chapter, we are interested in material flows at the community level and such local-level MFAs are rare. Some local MFAs have now been conducted, largely following the Eurostat principles of the national accounts; e.g. Grünbühel et al. (2003), Singh and Grünbühel (2003), Amman et al. (2002), Hobbes et al. (2007; Chapter 3) and Hobbes (2004). Some of these publications combine MFA with energy flow analysis (EFA) and assess the 'human appropriation of net primary production' (HANPP) as an additional characteristic of human-nature relations. The local MFA studies characteristically aim to link the MFA data with problems, concepts and theories that are relevant for rural communities, such as transition in modes of production, market incorporation, modernization, dependency and cultural change. These linkages remain quite weak, however. MFA has never been designed with such purposes in mind.

Against this background, the primary aim of this chapter is to develop and illustrate a system of material flow categories and aggregated indicators that provide explicit and quantitative linkages to important aspects of globalization, agricultural transition and (actual and potential)

food security. The designed classification and indicator system for rural MFA is referred to as rMFA.

The chapter is organized as follows. Section 4.2 lays down the principles underlying MFA flow categories and indicators in accordance with Eurostat. In section 4.3, the objectives for more local-level insight and theory-connected indicators for rMFA are discussed. Section 4.4 focuses on an operationalisation of these objectives, generating the indicators for material productivity, material intensity, material incorporation and food security, as well as categorization of flows that allow for the coherent and traceable calculations of these indicators. Next, section 4.5 describes the three research sites in Vietnam, the Philippines and Laos, as well as the research methods. Section 4.6 then gives the empirical results and the comparative insights. Finally, section 4.7 provides a discussion of the results in the broad context of societal change, environmental problems and MFA development. Data were gathered in the framework of the EU-funded project Southeast Asia in Transition (SEAtrans).[15]

4.2   Principles of MFA

This section provides a brief overview of general principles of material flow accounting, largely following the Eurostat guide (2001). MFA has been created to complement the standard national economic accounts, giving more insight into the physical dimension of the national economy (2000). The economy-wide MFA provides an overview, in tons or tons per capita, of annual material inputs and outputs of an economy. That way it becomes clear, for instance, how much material flow is associated with each dollar earned in a country.

In MFA, two system boundaries for material flows are defined. One (geographic) boundary determines what is part of the social system under study and what is part of other societies. The second boundary draws the distinction between the society and its so-called 'domestic environment' from which the society extracts materials and to which it disposes materials. Figure 4.1 gives an overview of the basic MFA model. Material flows are defined in MFA as displacements of materials di-

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[15]   Data for the Vietnam and Philippines case studies have been gathered by researchers from the Institute of Environmental Sciences, Leiden University (CML) together with researchers from the Center for Natural Resources and Environmental Studies, Hanoi University (CRES) and Isabela State University, Philippines (ISU). The Institute for Interdisciplinary Studies of Austrian Universities (IFF) worked together with National University of Laos (NUOL) for the Laotian case study.
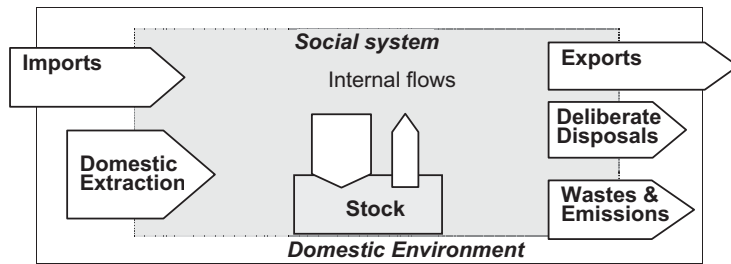
Figure 4.1 System components and flow categories in Material Flow Analysis. Adapted from Matthews et al. (2000). Following Eurostat, the social system is considered to comprise the human population, its domesticated animals (including aquaculture) and artifacts. The domestic environment then is the area where the population and their livestock dwell, and is considered to include agricultural plants.

rectly caused by human labour or labour substitutes. Displacements as a byproduct of intended extraction and not fit or intended for use ('hidden flows' in MFA terminology), such as mining overburden or soil erosion caused by agriculture, are usually omitted, as are non-anthropogenic, natural displacements.

Materials flowing into the social system are called 'inputs'. If inputs flow from the domestic environment to the social system, they are called 'domestic extraction' (DE); if inputs flow into the social system from foreign territories via an economic transaction, they are called 'import'. 'Outputs' from the social system flow either into a foreign territory (in which case the flow is categorized as an 'export') or to the domestic environment. The latter are divided into two categories, 'deliberate disposals' (DD) and 'wastes and emissions' (WE). If the material is disposed with a purpose, such as sowing seeds or applying fertilizer, the flow is called a DD. The waste and emission category is self-explanatory and includes all other flows. Internal flows are all those that do not cross the social system boundary.

The data of the various material flows can be aggregated to form new units, usually called indicators in MFA because they are constructed to express relevant system characteristics. Commonly used indicators are displayed in Table 4.1. Most of these borrow a few additional data from outside MFA proper, expressing flows in weights per capita or weights per dollar of GDP. One example is 'material intensity', which describes how many kg of material flows are associated with each dollar earned in the GDP. A decreasing material intensity indicates 'dematerializa-

Table 4.1 Definition and explanation of some MFA indicators

Direct Material Input (DMI) = Imports + DE	*Measures the material input of the economy*
Material Intensity = DMI/GDP	The degree to which the size of an economy (GDP) relates to material inputs. A reduction of DMI/GDP over time is called the 'dematerialization' of a society.
Direct Material Consumption (DMC) = DMI – Exports	Measures the material that remains in the social system or domestic environment, as wastes, emissions, deliberate disposal or addition to the material stock.
Physical Trade Balance (PTB) = Imports – Exports	If we assume that imports and exports tend to balance in financial terms, a society with a physical trade deficit indicates an exporter of relatively cheap, raw materials.
Net Addition to Stock (NAS) = closing stock – opening stock	This indicator measures the net physical growth of the economy.
Direct Processed Output (DPO) = DD + WE	Indicates the environmental impact of the society's outputs on its domestic environment.
Direct Material Output (DMO) = DD + WE + Exports	DMO is an indicator for the total environmental impact of a social system.

Source: Eurostat (2001)

tion' of an economy, which is then usually assumed to generate less environmental problems per dollar earned. It may now be revealed for instance that the economy of Brazil has grown in GDP terms but has not dematerialized, contrary to most developed countries (Amann et al., 2002). Well-designed aggregated indicators link the flow data to relevant issues and processes.

4.3 Objectives for indicators and flow categories for rural MFA

The previous section showed that the indicator of material intensity is linked to relevant issues at the national level. At the level of a rural village in a developing country, however, the material intensity indicator would be totally dominated by a purely incidental presence, of say, a hospital or a government unit (resulting in large cash flows without significant material flows). To take another example, the indicator of 'net addition to stock' (NAS) in such a village, would be fully dominated by the building of a concrete house in a certain year and would not be an indicator of any relevant ongoing process. Obviously, the design of aggregated indicators needs to be rethought for local MFA applications.

First, a rural MFA should retain the capacity to calculate important aggregated indicators of standard MFA, so that the local and the national

MFAs will remain clearly linked. Especially the indicators of 'direct material input' (DMI) and 'direct material consumption' (DMC) seem to be important in this respect because these are used to assess the transitions from hunter-gatherer to agricultural, and from agricultural to industrialized societies (Grünbühel et al., 2003; Singh and Grünbühel, 2003; Weisz et al., 2001).

Second, the local MFA should be connected to problems, processes and theory that stand central in rural societies. In this chapter, the focus is on (1) agricultural transition, (2) globalization and (3) food security.

Agricultural transition and intensity

Agricultural transition is defined as a change in the nature of the agricultural system. In line with MFA authors who distinguish between hunter-gatherer, agricultural and industrial societies Weisz *et al.* (2001), we distinguish between extensive, intensive and industrial agriculture, as we focus upon differences between communities that are primarily agricultural.[16] Transition, then, is the change from one system to the other. With that, we enter a much debated area within economic geography, based on the seminal work of Boserup (1965) and enriched of late by the case study of Machakos district in Kenya by Tiffen et al. (1994). This describes an example of massive change from an unsustainable extensive system to sustainable intensive agriculture with higher incomes per capita in spite of (or, as the argument goes, due to) a tripling in population density. There are several difficulties facing the seemingly obvious task of defining the boundaries between extensive, intensive and industrial systems by way of the material flows. Just like intensive systems, extensive systems may have a high production per capita, for instance, and be quite market-oriented. The same difficulty was encountered by Boserup, and her solution was to define the boundary between extensive and intensive systems simply by way of the number of croppings per year. For MFA studies, we suggest to follow the same course. That is, we may define qualitatively whether a system is extensive (with fallowing etc.), intensive (without fallows etc.) or industrial agriculture (e.g. factory farming or heated glasshouses), or of a mixed nature.

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[16]   This commonly used terminology is in fact confusing, suggesting as it does that intensification (higher inputs of labor and/or capital per hectare) is the same as a qualitative system change. Better words for the three types of agriculture could be: space-based agriculture, labor-based agriculture and capital-based agriculture – using space, labor and capital, respectively, as the major input to keep up profitability and sustainability of the enterprise.

This then leaves the MFA study free to empirically investigate if system type and transition are visible, quantitatively, in the material flows. We may then find, for instance, that intensive systems have a higher material input per produced ton. Alternatively, we may find that the intensification has been purely 'labour-led' (Clay et al., 1998), e.g. by way of intensified weeding, mulching and terracing, as found, for instance, with the Ifugao rice terraces in the Philippines, the Mafa in Cameroon (Zuiderwijk, 1998), and the Classic Maya (Johnston, 2003). Both ways of intensification may result in high agricultural production per hectare. In order to make such findings possible, the classification of material flow categories should of course include material inputs into agriculture and productivity of arable land. Indeed, the classification of Table 4.2 distinguishes between imported (i.e. monetary) and domestically extracted inputs to arable land. Section 4.4 will provide more details.

Globalization and incorporation

The next issue of theoretical importance is the relationship of MFA with the globalization concept. Globalization may be divided in two different processes: cultural and economic globalization (Giménez and Gendreau, 2001). Cultural globalization denotes the emergence of a global field of culture (values, storylines, images) where Western culture has a strong influence on nations, communities and individuals worldwide (Arnett, 2002). 'Localization' is often mentioned as a response to this influence, denoting that communities counterbalance the globalization tendencies by re-asserting their own cultural identities (Appadurai, 1990). Economic globalization denotes the creation of a strong world market into which more and more communities are taken up, both at the 'input side' of the consumer goods and services they use and at the 'output side' of the goods they supply. MFA cannot express cultural globalization but it can express economic globalization. The term of 'incorporation' will be used here to denote a community's degree of involvement in outside markets on both the input and output side of the community's economy (Galjart, 1986). Following Marx, rural sociologists such as Zuiderwijk (1998) emphasize the latter distinction because incorporation at the input side is viewed as entailing a deeper dependency and a deeper cultural impact than incorporation on the output side. Bolhuis and Van der Ploeg (1985) distinguish between three types of agriculture: 'subsistence agriculture' for farmers that are uninvolved in markets on both the input and the output side, 'incorporated agriculture' for farming with a high degree of incorporation on the input side and 'independent agriculture' for farming with a high degree of incorporation on the output side without relying on external inputs. Such farmers do exist indeed, such as the Kofyar of northern Nigeria described by Netting

(1993), or the Frisian cattle farmers in the Netherlands that were already fully market-oriented in the Middle Ages, or Hyden's (1980) 'uncaptured' African peasant who easily withdraws from the market system. On the other hand, farmers may also be forced into cash cropping or cash extraction because of sheer poverty, as the case of Tat in Vietnam (Section 4.6) will show.

It should be borne in mind that incorporation is not inherently connected to transition and intensification. Qualitative changes in agricultural practices may occur, for instance, due to population pressure rather than external markets and the other way around, an extractive (hunter-gatherer) society may be taken up in commercial orbits if their forest products find a world market, but continue to be an extractive society without system change. In MFA therefore, the input-side and output-side incorporation indicators should be kept separate from the intensity indicator(s). Section 4.4 provides more details on how the incorporation indicators are constructed.

Food security and dependency

Finally, MFA may be connected to the food security concept, a key issue for millions of people and communities in the developing countries. Food security is usually expressed using the single parameter of calories per person or per kilogram of body weight, and that simplification will be adopted here. Food security, then, is the degree to which one can grow, extract or buy the calories one needs. This definition keeps clear that hunger and mass starvation may occur also in times of relative food abundance, and that well-salaried people surrounded by well-working food markets are food secure also without growing anything (Sen, 1981).

To fully grasp the food security concept, therefore, incomes of people should be included. In this study however, we only focus on material flows. The actual food situation in a village may then be assessed, including the imports and exports on the food market. Of special interest, especially for developing countries, are four other non-economic calorific food security indicators concerning self-sufficiency and autarky. The first of those is the degree to which a community itself actually grows and extracts the calories it needs; this is the actual degree of food self-sufficiency (Pfister, 2003).[17] In this indicator, the food imported is excluded and the food exported is included. The latter could also be locally

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[17]   This is one of the indicators used by Pfister (2003), who assesses degree of self-sufficiency for staples of both human and livestock in flows per crop.

consumed, however. Excluding the exports, the second indicator is revealed: the potential degree of food self-sufficiency. Going deeper in the production process, the autarky indicators take the dependence on inputs from the market in the agricultural system into account. The first food autarky indicator is the degree to which a community could continue to produce the calories it needs without changing its present agricultural system and without depending on external markets; this could be called the degree of actual autarky. The second, most basic food autarky indicator expresses the degree to which a community would be able to feed itself when its own, domestic resources would be better utilized; this could be called potential autarky. Again, section 4.4 will provide more detail.

4.4 The rMFA flow categories and indicators

In order to calculate the indicators discussed in the preceding section, we need a well-structured system of categories of material flows. Table 4.2 presents the material flow categories used in the present study, with some examples added. This section first discusses the basic flow categories, then the sub-categorization of the flows at the input side and at the output side, and finally the indicators of productivity, intensity, incorporation and food security.

Basic flow categories

Table 4.2 follows the Eurostat MFA categories of import, domestic extraction (DE) and export. At this point, a terminological issue needs to be addressed. In Eurostat MFA, everything that 'comes from the land', be it forest products or intensively grown corn, is called 'extraction'. This category then includes the products from agriculture plus what is called 'extraction' in daily language and in terms such as 'extractive economies' (Ossewijer, 2001). In this natural usage, 'extraction' denotes everything that comes from the land without people investing in the maintenance of the resource (Weisz et al., 2001); examples are hunting, fishing from natural waters, natural grazing, logging or the extraction of non-timber forest products (NTFP). In order to avoid confusion, the Eurostat MFA category of domestic extraction will be marked here as DE and all other use of the terms agriculture and extraction will follow the natural nomenclature, denoting subcategories of DE.

In Table 4.2, the Eurostat categories of deliberate disposal (DD) and wastes & emissions (WE) are not taken up, because these are not related to the indicators of prime interest for local rMFA (see previous

Table 4.2   The material flow categories of rMFA, with some examples added

INPUT
IMPORTS
Import of consumer goods (IMPcons)
    for humans (IMPhum), e.g. food, beverage, consumptive fuel, sand for construction
    of and for animals (IMPliveaqua), e.g. livestock feed, salt, young livestock, fish feed, fish breed
Import of agricultural inputs (IMPag), e.g. seeds, fertilizer, fuel for agriculture, others
Import for extraction (IMPextr), e.g. fuel for extraction, other inputs for extraction
Import for infrastructure goods (IMPinfra), e.g. sand and gravel for infrastructure, others
Import for other sectors (IMPother)
DOMESTIC EXTRACTION (DE)
Agriculture (AgDE)
    for humans (AgDEhum), e.g. food crops, non-food crops
    for agriculture (AgDEag), e.g. green manure
    for animals (AgDEliveaqua), e.g. fodder for livestock or fish, grown as crop or as crop by-product
Extraction (ExtrDE)
    for humans (ExtrDEhum), e.g. timber, food, fuel wood, NTFP
    for agriculture (ExtrDEag), e.g. green manure
    by and for animals (ExtrDEliveaqua), e.g. grazing by cattle or cut-and-carry grass, gathered feed for fish
Aquaculture (AquaDE)
Minerals (DEmin), e.g. sand and gravel
OUTPUT
EXPORT
From livestock and aquaculture (LiveaquaEXP)
    for humans (LiveaquaEXPhum), e.g. eggs, meat, fish
    for agriculture (LiveaquaEXPag), e.g. animal manure
    for animals (LiveaquaEXPliveaqua), e.g. offal or fishmeal for livestock feed
From agriculture (AgEXP)
    for humans (AgEXPhum), food and non-food, e.g. by crop
    for agriculture (AgEXPag), e.g. green manure
    for animals (AgEXPliveaqua), e.g. exported fodder crop or feed corn
From extraction (ExtrEXP)
    for humans (ExtrEXPhum), e.g. timber, NTFP, gathered food, caught fish
    for agriculture (ExtrEXPag), e.g. bat dung fertilizer
    for animals (ExtrEXPliveaqua), e.g. exported hay
Minerals (MinEXP)
Mixed products (MixedEXP)
(Human consumption from livestock and aquaculture production, e.g. meat, eggs, fishpond fish)

PRE-CONSUMPTIVE AND PRE-EXPORT LOSSES FROM DE (LostDE)
From agriculture (LostAgDE)
    for humans (LostAgDEhum), e.g. rice husk
    for animals (LostAgDEliveaqua), e.g. cobs of yellow corn or feed as crop by-product

for agriculture (LostAgDEag), e.g. from green manure

From extraction (LostExtrDE)

for humans (LostExtrDEhum), e.g. from fruits or wild animals, and timber processing losses

for agriculture (LostExtrDEag), e.g. from bat dung fertilizer

for animals (LostExtrDEliveaqua), e.g. from cut-and-carry grass

From minerals (LostMinDE)

INPUTS INTO AGRICULTURE, ANIMAL HUSBANDRY AND EXTRACTION

Import of agricultural inputs (IMPag), e.g. seeds, fertilizer, fuel for agriculture, others

Import for extraction (IMPextr), e.g. fuel for extraction, other inputs for extraction

Import for animals (IMPforliveaqua), e.g. livestock feed, salt, fish feed

Agriculture for agriculture (AgDEag), e.g. green manure

Agriculture for animals (AgDEforliveaqua), e.g. fodder for livestock or fish grown as crop or as by-product

Extraction for agriculture (ExtrDEag), e.g. green manure

Extractivion for animals (ExtrDEforliveaqua), e.g. cut-and-carry grass, gathered feed for fish

Inputs from domestic live/aqua/hum to agric (LiveINPUTag), e.g. animal manure, night soil, compost from fishpond sediment

(Total animal manure)

section) and local pollution is no subject of this study. Instead, two other basic categories have been taken up, called 'pre-consumptive and pre-export losses from DE' and 'inputs into agriculture, animal husbandry and extraction' that enable the calculation of the food security and intensity indicators, respectively. The Eurostat MFA category of DD may be largely calculated from elements of the category 'inputs into agriculture, animal husbandry and extraction', e.g. by summing the fertilizers, seeds, fodder fed to livestock and green manure; extra are the inputs of fuel and machines. By way of the categories of import, DE and export, the standard indicators of direct material input (DMI), direct material consumption (DMC) and physical trade balance (PTB) may be calculated, e.g. for purposes of comparison with national MFAs (Grünbühel et al., 2003; Singh and Grünbühel, 2003; Weisz et al., 2001).

The flow sub-categories (input side)

The sub-categorization in Table 4.2 explicates boundary crossing and the internal flows by distinguishing between types of origin and destination. Within the basic category of import, a distinction is made between consumption goods and production (capital) goods and, within the latter category, between extraction, agriculture and other sectors, except for infrastructure that benefits all sectors.

Drawing a distinction between extraction (commercial or subsistence) and agriculture is needed to identify different modes of production.

The categories also enable the calculation of some of the material incorporation, intensity and food security indicators. Imports of capital goods for the secondary, tertiary and quaternary sectors have been lumped as 'other sectors' because of our rural focus. They may of course be disaggregated in other cases.

Within the sub-category of import of consumer goods, it is necessary to distinguish between 'for humans' and 'for animals' (livestock and aquaculture); this is a key for analyzing the food security situation.

On the final level of disaggregation, the table only gives examples such as 'food', 'feed', 'breed', or 'consumptive fuel'. These may be filled in differently for each separate study. Table 4.4, where all categories are quantified for the three villages, gives more examples.

Within the basic category of DE, the first distinction is between sources. Biomass has to be distinguished from minerals. 'Agriculture' refers to all the harvested agricultural products. 'Extraction' has already been defined. 'Aquaculture' refers not to the fish but to plants picked from fishponds; in the chosen system definition, the fish belongs to the social system like livestock. Within these source categories of DE, Table 4.2 makes a further distinction into destinations, such as 'for humans' and 'for livestock' for reasons already given. 'Agriculture' refers to internal recycling of agricultural products, e.g. in the form of mulching. The same subdivision by destinations is made within the category of 'extraction'; many products will be destined for humans but natural grazing is an important category too. 'For agriculture' here refers, for instance, to tree leaves brought to the fields for fertility enhancement (Van Beek and Banga, 1992).

The flow sub-categories (output side)

On the output side of Table 4.2, export is the first basic category, using comparable categories as on the input side: first sources and then destinations. Home consumption of domestic animal products (e.g. meat, eggs, milk and aquaculture production) is included between brackets here. It cannot be added up with the rest of the basic category because it is not an export, but there does not exist any conceptually possible place for it in Eurostat MFA, because humans and domesticated animals both belong to the social system and the consumption cannot be accounted for. The figure may be of interest to several potential indicators, however.

As said, the MFA category of wastes & emissions is not fully represented in the table. The same holds for the overall input-output balancing, even if a core concept for national level MFA. Instead, the category of 'pre-consumptive and pre-export losses from DE' (LostDE) is fully geared towards the calculation of the incorporation and food security indicators. The focus is only on DE flows destined for human use in the village or for export. In the DE subcategories, these flows are often expressed in terms that are not precise enough yet for a proper assessment of these indicators and to the degree that this is the case indeed, the 'LostDE' category aims to repair this. Take, for instance, the extraction of timber. Round logs may be transported to a village for slicing before selling and loose, say 50% of their weight in the process. If the indicator for output market would compare DE directly with the exports, the outcome would be that the degree of incorporation is 0.5 while in fact all logging is fully exported. The 'LostDE' category then first states the lost 50%, so that DE minus 'LostDE' may be compared with the export and the indicator ends with the proper 1.0 as degree of incorporation. The same goes for human consumption; if rice flows are expressed in tons of paddy, for instance, milling losses have to be subtracted first. Note that this holds irrespective of whether the 'losses' are in fact wasted or put to some good use (deliberate disposal).[18]

The category in Table 4.2 of 'Inputs into agriculture, animal husbandry and extraction' is geared towards the sound calculation of the agricultural intensity indicators. It starts with the categories of imports, agriculture and extraction for agriculture, animals and extraction, and adds inputs from domestic livestock, aquaculture or humans to agriculture.[19] The distinction between the sources and destinations of the material flows enables the assessment of the four intensity indicators mentioned below.

The total amount of animal manure compared to animal manure used on the agricultural fields is important to indicate potential types of land use and to calculate the potential autarky indicator. Because of the Eurostat MFA structure as used in this study, there is no conceptually correct position for the category total animal manure and it is therefore put between brackets.

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[18]   The category of LostDE resembles the MFA category of hidden flows and the Eurostat MFA category of "unused domestic extraction" in particular. LostDE focuses on exported materials and foodstuffs only, however, and only on what is in fact exportable and edible in these categories.

[19]   This category matches largely with the standard MFA category of deliberate disposal but adding fuel and equipment.

Material productivity (MPROD) indicators

Table 4.3 provides the descriptive and formal notation of the indicators in terms of the categories used in Table 4.2. After mentioning some standard MFA indicators, the first rMFA indicators concern material productivity (MPROD), characterizing the output side of the agricultural system. Productivity may be expressed in tons per capita and in tons per hectare. This distinction is important because tons-per-capita and tons-per-hectare lie close to the concepts of 'returns-to-labour' and 're-turns-to-land', respectively, that are central economic parameters of farming systems. In general, extensive systems (i.e. with low capital and labour inputs) under conditions of land abundance will tend to have high production per capita and low production per hectare, and inten-sive systems under conditions of land scarcity will tend to the reverse characteristics. This way, the productivity indicators are related to the material intensity indicators described below. However, a high produc-tion per hectare does not inevitably imply high material intensity, be-cause much of the productivity may depend on land and climate quality and on the labour, rather than material inputs.

Six productivity indicators are designed on the basis of Table 4.2. The 'rice productivity' is put first, because rice in South East Asian villages is the cornerstone of the subsistence economy. Then, the 'total produc-tivity of agriculture' includes rice but also other crops such as corn or tubers, and the 'total productivity of extraction' includes all extracted products. They are all expressed in kg per capita per year and in tons per hectare per year. In the last 'extraction' indicator in Table 4.3, 'ex-tractive land' may often be taken as the village territory minus the ara-ble land; in other cases, rocks and badlands may be excluded.

Material intensity (MINT) indicators

Agriculture and animal husbandry are called intensive if they apply high levels of inputs per hectare or per capita. The group of intensity in-dicators will be referred to as 'material intensity' because MFA focuses on material flows only, excluding the labour and capital components. Based on the category of 'Inputs into agriculture, animal husbandry and extraction' (Table 4.2), a number of indicators for the material input intensity can easily be calculated as displayed in Table 4.3. A distinction is made between intensity of agriculture focused on only imported in-puts ('imported material intensity of agriculture') and on all inputs ('to-tal'), both which may be expressed in kg per capita per year or in tons per hectare of arable land per year. The imported material intensity of agriculture is allied to the incorporation phenomenon, see below. Indi-

Table 4.3 The rMFA indicators used in the present study

Standard MFA indicators
- Direct Material Input (DMI) = Imports + DE [tons/cap/year]
- Direct Material Consumption (DMC) = DMI – Export [tons/cap/year]
- Physical Trade Balance (PTB) = Imports – Exports [tons/cap/year]

Material Productivity (MPROD)
- Rice Productivity in kg/cap (PRODofRice/cap) = production of rice [kg] per capita per year = AgDEhum rice [kg/cap] + 0.65* AgDEag rice seeds [kg/cap] + AgDElive rice [kg/cap]
- Rice Productivity in tons/ha (PRODofRice/ha) = production of rice [t] per hectare of rice field per year = (AgDEhum rice [t/ha] + 0.65*AgDEag rice seeds [t/ha] + AgDElive rice [t/ha]
- Total Productivity of Agriculture in kg/cap (TPRODofAg/cap) = total agricultural production [kg] per capita per year = AgDE [kg/cap]
- Total Productivity of Agriculture in tons/ha (TPRODofag/ha) = total agricultural production [t] per hectare arable land per year = AgDE [tons/ha]
- Total Productivity of Extraction in kg/cap (TPRODofextr/cap) = total extraction [kg] per capita per year = ExtrDE [kg/cap]
- Total Productivity of Extraction in tons/ha (TPRODofextr/ha) = total extraction [t] per hectare of extractive land = ExtrDE / total area minus arable land [t/ha]

Material Intensity (MINT)
- Imported Material Intensity of Agriculture in kg/cap (IMINTofAg/cap) = inputs [kg] from import to agriculture per capita per year = IMPag [kg/cap]
- Imported Material Intensity of Agriculture in tons/ha (IMINTofAg/ha) = IMPag [t/ha]
- Total Material Intensity of Agriculture in kg/cap (TMINTofAg/cap) = inputs [kg] into agriculture per capita per year = IMPag [kg/cap] + AgDEag [kg/cap] + LiveINPUTag [kg/cap]
- Total Material Intensity of Agriculture in tons/ha (TMINTofAg/ha) = inputs [t] into agriculture per ha arable land per year = IMPag [t/ha] + AgDEag [t/ha] + LiveINPUTag [t/ha]
- Total Material Intensity of Livestock keeping in kg/cap (TMINTofLive/cap) = total of all feed (imported and from DE) for domestic livestock, [kg] per cap per year = IMPforlive [kg/cap] + AgDEforlive [kg/cap] + ExtrDEforlive [kg/cap] - AgEXPlive [kg/cap] - ExtrEXPlive [kg/cap] - LostAgDElive [kg/cap] – LostExtrDElive [kg/cap]

Material Incorporation (MINC)
- Material Incorporation of Agriculture, input side (MINCinputsAg) = Import for agriculture / Total inputs to agriculture = IMPag / (IMPag + AgDEag + LiveINPUTag)
- Material Incorporation of Agriculture, output side (MINCoutputAg) = Agricultural Export / (Agriculture – Lost agriculture) = AgEXP / (AgDE – LostAgDE)

- Material Incorporation of Extraction, output side (MINCoutputExtr) = Export of extracted products / (Extraction – Lost extraction) = ExtrEXP / (ExtrDE – LostExtrDE)
- Total Material Incorporation, output side (TMINCoutput) = Export of agricultural and extractive products/ (Agriculture and Extraction – Losses from agriculture and extraction) = (AgEXP + ExtrEXP) / (AgDE + ExtrDE – LostAgDE – LostExtrDE)
- Material Incorporation of Consumption (MINCofcons) = Imported consumer goods for humans / (Imported consumer goods for humans + DE for humans – Exports of those goods – Lost DE of those goods) = IMPhum / (IMPhum + AgDEhum + ExtrDEhum - LostAgDEhum – LostExtrDEhum - AgEXPhum – ExtrEXPhum)[a]

Food security [b]
- Actual degree of food Consumption-Sufficiency (ACSfood) = (Imports of human food + DE of human food – Lost DE of human food – Export of human food) / Food need = (Imphumfood + AgDEhumfood + ExtrDEhumfood - LostAgDEhumfood - LostExtrDEhumfood - AgEXPhumfood - ExtrEXPhumfood) / Food need
- Actual degree of food Self-Sufficiency (ASSfood) = (DE of human food – Lost DE of human food – Export of human food) / Food need = (AgDEhumfood + ExtrDEhumfood - LostAgDEhumfood – LostExtrDEhumfood- AgEXPhumfood - ExtrEXPhumfood) / Food need
- Potential degree of food Self-Sufficiency (PSSbare) = (DE of edible human food – Lost DE of edible human food) / Food need = (AgDEhumbare + ExtrDEhumbare - LostAgDEhumbare – LostExtrDEhumbare) / Food need
- Actual Autarky (AAbare) = (DE of edible human food – Lost DE of edible human food – 4*fertilizer input) / Food need = (AgDEhumbare + ExtrDEhumbare – LostAgDEhumbare – LostExtrDEhumbare – 4*fertilizer input for DE bare) / Food need
- Potential Autarky (PAfood) = (DE of human food – Lost DE of human food – 4*fertilizer input + 1*excess animal manure) / Food need = (AgDEhumfood + ExtrDEhumfood - LostAgDEhumfood – LostExtrDEhumfood – 4*fertilizer input for DE humfood + excess animal manure) / Food need

[a] Sand, gravel and cement are not included as consumption good.
[b] Consumption of livestock and livestock products is not included in the food security indicators

cators of the imported material intensity of extraction (IMIofExtr, etc.) may be defined analogously but will usually be less important. The intensity of livestock keeping is the livestock feed imported or extracted and fed to the livestock by humans (hence excluding natural grazing), in kg per capita per year.

One caveat may be mentioned here, that concerns the relative importance of organic and inorganic flows. Even if we take, as we should, the dry weight of animal manure (approximately 13 % of the wet-weight of feaces), would a ton of animal manure and a ton of fertilizer be of equal

relevance? This being only another example in a well-known issue surrounding MFA in general (Kleijn, 2001), this matter will only be pursued when discussing the food security indicators. In Table 4.4, the two flows have simply been added.

Material incorporation (MINC) indicators

This group of indicators will be called 'material incorporation' because, as said, MFA does not include the economic aspect. On the input side, the degree of material incorporation of agriculture is defined as the ratio of imported inputs into agriculture to the total of material inputs, see Table 4.3. This is a dimensionless indicator, varying between 0 and 1. When MINCinputAg = 1, agriculture draws all its material inputs from external markets and is therefore fully incorporated on the input side. Input-side incorporation of extraction (logging, fishing etc.) may be calculated analogously, but will usually be less relevant because these inputs, by nature, will usually be small (except in fishing communities).

Next, Table 4.3 describes the degree of incorporation of agriculture on the output side (MINCoutputAg), defined as the ratio of exported production to the total production of agriculture, corrected for the processing losses. This dimensionless indicator will run up to 1 in cases of fully market-oriented production and be close to zero in subsistence agriculture. The degree of incorporation of extraction of products such as timber and NTFP (MINCoutputExt) is calculated analogously, as Table 4.3 describes. To calculate the total degree of incorporation on the output side, the total flows of agriculture and extraction should be taken. Again, see Table 4.3 for the formal expressions. Averaging the incorporation indicators of the input and the output sides does not make much sense, because a village with high external inputs and low external outputs is in a very different (and more problematic) situation from a village with the reverse characteristics.

Besides the incorporation of agriculture and extraction, the degree of incorporation in consumer markets may be of interest, e.g. for a connection with the process of economic globalization. Material incorporation of consumption (MINCofCons) is expressed as the imported divided by the total consumption. Table 4.3 shows the precise notation.

Food security indicators

As discussed in the previous section, five indicators may be constructed that express the calorific food security situation of a rural community. One basis for the calculations is the food need per capita, visible in all

denominators in the expressions of Table 4.3. Following most statistical approaches (e.g. of the FAO), focus in this chapter is on calorific needs only, hence leaving out proteins, trace metals, vitamins and so on. Calorific need for an average rural adult in the developing world is 2500 kcal per day or, with uncooked dry white rice delivering about 363 kcal per 100 grams, 252 kg of that rice per year (WHO, 1985). In South East Asia, all other foodstuffs may be converted to the rice equivalence value. In this chapter, the conversion factor is 1/3 for banana, potato, cassava and corn, 1/10 for bamboo shoots and an assumed factor of 1 for imported foodstuffs.

The actual degree of food consumption-sufficiency (ACSfood) reflects the actual calorific situation in the village. With all components expressed in kg rice equivalence per capita, this is a dimensionless indicator that denotes theoretical full consumption-sufficiency if 1 or above. In practice, the outcome should be more than 1, in order to compensate for seasonal variations, unequal wealth distribution, unused food leftovers, and so on. Some compensation of these factors is achieved by using the food needs of adults rather than some average of adults and children.

The second food security indicator in Table 4.3, the actual degree of food self-sufficiency (ASSfood), expresses the degree to which a community actually feeds itself, hence, with imports left out. The indicator denotes full self-sufficiency if 1 or above. A discussion now becomes relevant as to what in fact constitutes 'human food', since usually, not all edible things are regarded as human food locally. Thus, a choice has to be made as to what is regarded as human food out of the usually long list of things produced in a village. In our Philippines village, for instance, people grow much yellow corn but they do so for the pig feed market; it is considered unfit for dignified human consumption (and very difficult to store anyway). A likewise role is played by cassava in the Vietnamese village. In this chapter, we take the community's own preferences as the default basis for the ASS calculation; if a choice for all edible stuff is taken, the indicator is called 'ASS in bare calories' (ASSbare).

The degree of food self-sufficiency as defined above reflects the actual food situation but may at the same time be regarded as only a surface characteristic, because the food exported by the community could also be consumed domestically. Thus, an indicator called 'potential degree of food self-sufficiently' describes the degree to which the community grows and extracts enough food to feed itself if necessary (e.g. if the terms of trade between import and export would deteriorate dramati-

cally). In times when markets would fail, a community is likely to broaden its definition of what is edible; hence, the logical line is to take all edible food in the equation here. The quantitative and formal notations of the potential degree of food self-sufficiency (PSSbare) indicator are found in Table 4.3.

As a next step in the exploration of the food security and dependency of a community, we may calculate whether a community could also survive without external inputs in agriculture. Thus, the indicator of 'actual food autarky' is defined as the degree to which the community would be able to feed itself if input and output markets would fall away instantaneously (e.g. due to war or natural disaster). In this equation (see Table 4.3), focused as it is on bare essentials, all edible material should again be taken in stead of only the culturally preferred foodstuff. Part of the equation is an estimate of how many kg of grains may be produced per kg of external inputs (especially fertilizer). We have taken a factor of 4 here, based on the production function of rice in the research sites.[20]

The degree of actual food autarky does not reflect that on the longer run, communities may adapt to input and output market problems. One opportunity, accessible through rMFA, is to make the farming system more organic and use all the available animal manure in the village as input for agriculture. 'Excess animal manure' in Table 4.3 is all animal manure the community is not using yet (i.e. total animal manure minus the amount of animal manure used as agricultural inputs in Table 4.2). Then, assuming that 1 kg of (dry weight) animal manure can be converted into 1 kg of grains, the indicator of 'potential food autarky' describes the degree to which the community would be able to feed itself, on the longer run. This indicator expresses the basic independence of the community *vis à vis* the external (input and output) markets. If 'potential food autarky' exceeds 1, farmers may enter input and output markets voluntarily. To express this properly, the culturally preferred foodstuffs should be taken up in this equation, hence not the bare calories.

This way, we may characterize any rural community with a 'food security profile' of five indicators. Examples are in Section 4.6.

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[20]   For corn the factor should be 10, based on the production function of corn (Yield = 1016 + 10.53 * Fertilizer) in Dy Abra (with yield and fertilizer in kg/ha), see Hobbes and De Groot (2003).

4.5   Research sites and research methods

The villages chosen for comparison are Dy Abra in the Philippines, Tat in Vietnam and Nalang in Laos. The populations almost fully consist of smallholder farmers producing for subsistence and the market. First a short description of each research site is given, followed by an assessment of the modes of production and an overview of the research methods.

Dy Abra, covering an area of 2260 hectares, lies in the rolling landscape of Isabela Province between the Cagayan river and central highway in the west, and the mountainous Sierra Madre forest in the east. Moderately sloping and plane land in Dy Abra is primarily devoted to hybrid yellow corn (134 ha) grown for the burgeoning market for animal feed, and to rainfed and manually irrigated rice (total of 56 ha), grown for own use. In 2001, the village consisted of 549 people in 94 households. People still have a tradition of swidden ('slash and burn') cultivation and practiced (illegal) logging in the generally steeply sloping areas that are relatively far away from the village centre. Swidden fields were made by farmers that had no or limited access to permanent fields, covering an area of about 29 ha.

At 140 kilometres west of Hanoi and covering a total of 740 hectares, Tat hamlet is part of Tan Minh village, in the north of Hoa Binh Province, Vietnam. Most houses in the hamlet are found along the four-kilometre stretch of road that follows the river on the narrow valley floor, at 300 meter altitude, where most of the 22 hectares of paddy fields have been developed.[21] The valley is surrounded by mountains that reach 1000 meters within two kilometres of the road, resulting in steep slopes, often of 45 to 60 degrees. On these slopes people practiced swidden covering an area of about 47 hectares. In 2001, the population consisted of 466 persons, divided over 105 households. The village economy used to be completely based on subsistence production but since the arrival of the road in 1992 and its improvement in 1999, the hamlet has become deeply involved in market production. The people mainly make a living from a combination of irrigated rice and swidden farming, together with animal husbandry and the collection of forest products. Contrary to Dy Abra and Nalang, the village has a tax office, a post office, a health clinic, electricity (since 2001) and a bus that plies daily to the lowlands.

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[21]   The data on the sizes of paddies and swiddens and total area in Tat are based on remote sensing in 1998, taken from Cuc and Rambo (2001).

Nalang lies on the northern edge of the Vientiane Plain, where the flat and monotonous rice-growing area rises to forested hills around the town of Vang Viang and the Nam Ngum hydroelectric dam. While the valley bottom has been converted into paddies (139 hectare) including a system of irrigation, the higher levels are mainly covered with forest where pastures and swidden plots (totalling 23 hectares) are found. Nalang is characterized by a largely subsistence economy, based on traditional glutinous rice farming, with only one crop a year. For export, people are involved in some cucumber and banana agriculture, extraction of forest products and trade in cattle. The population in Nalang consisted of 702 people in 2001. The total area of Nalang is 1630 hectare.

As said, modes of production are to be assessed directly from people's activities. It then appears that the situation in all three villages is thoroughly mixed. In all three villages, people practice extraction (e.g. timber and NTFP), extensive (swidden) agriculture, single-cropping (rainfed) permanent agriculture and double-cropping, irrigated agriculture. In Nalang, the latter consists of dry-season cucumber on wet-season rice fields, and in the other two villages of double-cropped rice. At the same time, the mixtures may be scaled on a dimension of overall intensity. In Nalang, the great majority of the land is under single cropping of traditional rice varieties. People use stable manure on the fields and leave cattle to graze on the paddies. The cash crop cucumber is intensively cultivated. In Dy Abra, only imported fertilizers are used for both the hybrid corn and rice cultivation, of which most involve double cropping. In Tat, almost all rice fields are double-cropped and moreover, people apply fertilizer, and use much labour on green and animal manure management and keeping animals (pigs, ducks, fishponds) in an attempt at intensive, almost industrial animal husbandry – which in fact is failing due to high mortality rates.

Thus, modes of production cannot be characterized as simply 'extensive', 'intensive' or 'industrial'. Instead, Nalang is denoted as a mixture of low intensity, Dy Abra as a mixture of medium intensity and Tat as a mixture of high intensity. Tat appears to be a 'constrained ecosystem' (Agbo et al., 1993), where agricultural expansion would entail very high investment cost especially in terracing. In the next section, we will see if this characterization is reflected in the indicators of the rMFA.

The fieldwork in the three research sites took place between April 2001 and June 2002. The rMFA time frame was one year.[22] For data gather-

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22   During this period, the road in Tat was being paved. Because it is a one-time event dominating all the material flows in the village it was left out of the analysis.

ing focusing on basic socio-economics and the main material flows and stocks, a 100 percent sample of households was taken in Nalang and Dy Abra, while in Tat a random sample of 30 households was taken, based on an initial household survey covering all households. Methods used in Nalang were household questionnaires supplemented by structured and semi-structured interviews. The latter two were the main methods in the other two villages. Direct measurements were taken of buildings, fuel wood, wastes and food consumption. For additional quantitative and qualitative data on micro-economic and cultural matters, semi-structured household interviews, focus group discussions, topical interviews with key respondents, informal interviews for sensitive issues and participatory methods such as option ranking and historical diagramming were used in all research sites Chambers (1994). Primary reports on the villages are Hobbes and Kleijn (2006) on Tat, Hobbes and Kleijn (2007) on Dy Abra and Grünbühel (2004) on Nalang. Data from Nalang were furthermore interpreted for the present chapter by Grünbühel, which is gratefully acknowledged here.

How to account for the water content of biomass materials requires some attention here because it is as yet an unresolved issue in MFA. Eurostat (2001) recommends to account for the weight of products converted to a water content as typically reported in dominant statistical sources.[23] If, for instance, timber felled in the forest holds 45% water and the national timber statistics use a water content of 15%, one ton of felled timber should be taken up in the rMFA as 647 kg only. Analogous conversions would hold for bamboo shoots, fish, corn and so on. At the same time, however, the loads that people have to drag and carry are the real weights, not the 'statistical' ones. For a study that aims to reflect local realities rather than to link up with national statistics, therefore, an 'as is' approach could be used, as has been done, for instance, in the original Tat study (Hobbes et al., 2007; Chapter 3). The water content of most biomass materials is then variable, usually decreasing in the course of time between harvest and use. Data on the other villages did not allow this approach in the present study, however, and it was chosen to apply an 'as used' accounting instead, meaning that all weights have been converted to one water content, set as the content when the timber, fish, corn etc. is sold or consumed locally. For timber this water content is 35%.

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[23]   Various products will always have different water contents in statistics of various countries. To overcome the problem of varying water contents and to arrive at universal comparison of weights, the solution would be to use purely dry weights for all products in all MFAs.

4.6   Results: the rMFA indicators in the three villages

Table 4.4 shows the rMFA flow data for the three villages, organized si-
milar to Table 4.2. The sub-categories are chosen such that they still
show enough details to make out the main characteristics in the three
villages. Table 4.5 displays the outcomes of the indicators of which the
formulas are given in Table 4.3. This section will show that a well-
grounded insight in the rural systems is achieved by way of these indi-
cators and the underlying material flow data.

Standard MFA indicators

Starting out with the standard MFA indicators in Table 4.5, the direct
material input (DMI) shows that Nalang has less than half of the DMI
level of Dy Abra and Tat. As may be traced in Table 4.4, the main items
of DMI consist of DE (corn, natural grazing and timber in Dy Abra,
timber, natural grazing and firewood in Tat and natural grazing and
firewood in Nalang). It also shows that Nalang is much better off in rice
and much less busy with other forms of agriculture or extraction. The
amount of firewood used in Tat is more than twice the amount used in
the other two villages; people need much firewood to keep themselves
warm during wintertime due to Tat's mountainous landscape. Subtract-
ing the export from DMI in order to get the direct material consump-
tion (DMC), we see a steep drop in Dy Abra due to its huge exports of
corn and timber, totaling almost 3 tons per capita per year (see Table
4.4). Tat exports only one-third of this amount, and Nalang only one-
tenth. More than half of the difference in DMC between Tat and Dy
Abra is caused by the amount of firewood consumption in Tat. More in-
formation on these indicators is given in section 4.7.

Material productivity (MPROD)

The material productivity (MPROD) indicators show a wide range of di-
versity among the villages. The productivity of the rice (PRODofRice) in
kilograms per capita shows Nalang's favorable position with 289 kg per
capita per year. Dy Abra produces significantly less and Tat only half of
this amount. The low production per capita in Tat does not come about
by a low production per hectare. On the contrary, with 2.86 tons/ha, Tat
has the highest figure by far, with Nalang producing only half of that
amount and Dy Abra again in-between. This is the characteristic differ-
ence between extensive and intensive modes of production (Boserup,
1965); people in Tat, confined to their 22 ha of paddy land, put in much
effort per hectare, with some success in terms of output per hectare but

Table 4.4 Quantification of the rMFA categories displayed in Table 4.2 for the three villages

Village		*Dy Abra*	*Tat*	*Nalang*
Population		549	466	702
Arable land (ha)		219	69	175
Total land area (ha)		2260	740	1630
INPUT				
IMPORTS				
Import of consumer goods (IMPcons)				
for humans (IMPhum)	food (processed and unprocessed)	80	178	5
	sand & cement for construction	86	0	25
	wood & steel for construction	7	0	0
	other consumer goods	49	90	64
of and for livestock (IMPlive)	feed & young livestock	1	72	7
for aquaculture (IMPaqua)	feed & breed	0	3	0
Import for extraction (IMPextr)	fuel	11	2	0
	equipment	0.4	0.2	0
Import of agricultural inputs (IMPag)	seeds	31	3	0
	fertilizers	148	24	0
	fuel for agriculture	4	2	6
	equipment	2	0	2
DOMESTIC EXTRACTION (DE)				
Agriculture (AgDE)				
for humans (AgDEhum)	milled rice	149	99	283
	rice husk and bran	89	0	0
	corn (+cob)	20	0	0
	banana	36	5	23
	fruits, vegetables & herbs	36	49	266
	canna for export	0	77	0
	others food	36	36	4
	others non-food	0	0	308
for agriculture (AgDEag)	rice husk	0	0	105
	rice seeds	4	0	9
for livestock (AgDElive)	milled rice as feed	15	36	0
	rice bran and/or husk as feed	26	64	40
	corn (+cob)	1576	4	0
	roots & tubers as feed	26	112	7
	mixed feed, including leaves	33	142	0
	straw from rice as feed	0	0	97
for aquaculture (AgDEaqua)	leaves from agricultural by-product in fishpond	0	599	0
	rice bran for fish	0	9	0
Extraction (ExtrDE)				
for humans (ExtrDEhum)	timber	1572	1219	340

		fuel wood & fuel bamboo	308	1133	476
		NTFP non-food	10	151	236
		NTFP food	4	134	87
	for agriculture (ExtrDEag)	green manure	0	19	0
		bamboo for fencing	0	2	252
	by and for livestock (ExtrDElive)	grazing by cattle	1679	1064	335
		cut-and-carry grass	0	150	0
	by and for aquaculture (ExtrDEaqua)	cut-and-carry grass and leaves	0	121	0
Aquaculture (AquaDE)		water vegetable	0	116	0
Minerals (DEmin)		sand and gravel	55	0	0
OUTPUT					
EXPORT					
From livestock and aquaculture (LiveaquaEXP)					
	for humans (LiveaquaEXPhum)	livestock	2	26	10
From agriculture (AgEXP)					
	for humans (AgEXPhum)	milled rice	7	0	49
		cucumber	0	0	71
		banana	0	1	14
		canna	0	77	0
		ginger	0	11	0
	for livestock (AgEXPlive)	corn	1361	0	0
From extraction (ExtrEXP)					
	for humans (ExtrEXPhum)	timber	1550	837	177
		NTFP non-food	0	133	129
		NTFP food	0	92	0
(Human consumption from livestock and aquaculture production)			(31)	(13)	
PRE-CONSUMPTIVE AND PRE-EXPORT LOSSES FROM DE (LostDE)					
From agriculture (LostAgDE)					
	for humans (LostAgDEhum)	corncob waste	2	0	0
		rice husk and bran	89	0	0
	for livestock (LostAgDElive)	corncob waste	153	0	0
From extraction (LostExtrDE)					
	for humans (LostExtrDEhum)	timber processing losses	0	367	0
INPUTS INTO AGRICULTURE, ANIMAL HUSBANDRY AND EXTRACTION					
Import of agricultural inputs (IMPag)		rice seeds	4	3	0
		corn seeds	27	0	0
		other seeds	0	1	0
		fertilizer for rice	46	24	0
		fertilizer for corn	102	0	0
		fuel for agriculture	4	2	6
		equipment	2	0	2
Import for extraction (IMPextr)		fuel and equipment	11	2	0
Import for animals (IMPforlive)		feed	0	67	0

Agriculture for agriculture (AgDEag)	rice seeds	4	2	9
	rice husk	0	0	105
Agriculture for livestock (AgDEforlive)	total feed	1674	358	144
Extraction for agriculture (ExtrDEag)	bamboo for fencing	0	2	252
	green manure	0	19	0
Extraction for livestock (ExtrDEforlive)	cut-and-carry grass	0	150	0
Inputs from domestic live to agric (LiveINPUTag)	animal manure	0	489	53
(Total animal manure)		(838)	(590)	(215)

Areas are given in hectares, the weights of the material flows are given in kilogram per capita per year. In all figures, the first two digits are significant.

concomitant low production per capita and, assuming that people work hard in such circumstances, low returns to labour.[24]

The total productivity of agriculture (TPRODofAg) shows only a small increase compared to rice in Nalang, but great jumps in Dy Abra and Tat. Table 4.4 shows that this is largely due to the corn production in Dy Abra and to a wider range of products in Tat, mainly coming from the swiddens. Table 4.4 also shows that much of this in Tat is fed to the village's livestock and fish, while the corn of Dy Abra, although livestock feed too, is fully exported.[25]

The indicators of productivity of extraction (TPRODofExtr) show that the extractive activities (of timber, firewood, natural grazing, NTFP, etc.) in all villages generate larger flows than the total of agriculture. With Table 4.4 it can be calculated that this even largely holds when natural ('extractive') grazing is left out. In terms of kilograms, therefore, even Tat and Dy Abra, in spite of their intensive agriculture and large amounts of corn respectively, could still be called extractive economies. In terms of flows of extraction per capita, Tat with almost 4 tons and Dy Abra with 3.5 tons are much higher than Nalang. In terms of extraction per hectare, Dy Abra comes closer to Nalang (both around 1 ton per hectare), but Tat remains at almost 3 tons per hectare per year, due to its low total surface. What could be the matter here? It is hard to imagine an extractive system that could deliver a production just as high as irrigated and heavily manured rice fields. Indeed, in Tat the extraction is unsustainable (Hobbes et al., 2007; Chapter 3). Methodologically for rMFA, it is a

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[24] The production of rice per hectare per year (one or two crops) concerns the yield of dry white rice as displayed in Table 4.4; the areas of the few swiddens planted in rice have been neglected (while the yields of the swiddens are included).

[25] The figure of Tat is somewhat distorted because of the 599 kg/capita of cassava leaves that are put into the fishponds; it is not known if this effectively acts as fish feed or is in fact more a type of very wet compost making.

Table 4.5   The outcomes of the rMFA indicators in the present study

Indicators	Dy Abra	Tat	Nalang
Standard MFA indicators			
Direct Material Input (DMI) [tons/cap/year]	6.1	5.7	3.0
Direct Material Consumption (DMC) [tons/cap/year]	3.2	4.5	2.5
Physical Trade Balance (PTB) [tons/cap/year]	-2.5	-0.8	-0.3
Material Productivity (MPROD)			
Rice Productivity in kg/cap (PRODof Rice/cap)	167	135	289
Rice Productivity in tons/ha (PRODofRice/ha)	1.64	2.86	1.46
Total Productivity of Agriculture in kg/cap (TPRODofAg/cap)	2046	1232	1142
Total Productivity of Agriculture in tons/ha (TPRODof Ag/ha)	5.13	8.32	4.58
Total Productivity of Extraction in kg/cap (TPRODof Extr/cap)	3572	3994	1726
Total Productivity of Extraction in tons/ha (TPRODof Extr/ha)	0.96	2.77	0.83
Material intensity (MINT)			
Imported Material Intensity of Agriculture in kg/cap (IMINTofAg/cap)	184	30	8
Imported Material Intensity of Agriculture in tons/ha (IMINTofAg/ha)	0.46	0.20	0.03
Total Material Intensity of Agriculture in kg/cap (TMINTofAg/cap)	188	543	427
Total Material Intensity of Agriculture in tons/ha (TMINTofAg/ha)	0.47	3.67	1.71
Total Material Intensity of Livestock keeping in kg/cap (TMINTofLive/cap)	161	575	144
Material incorporation (MINC)			
Material Incorporation of Agriculture, input side (MINCinputsAg)	0.98	0.05	0.02
Material Incorporation of Agriculture, output side (MINCoutputAg)	0.76	0.07	0.12
Material Incorporation of Extraction, output side (MINCoutputExtr)	0.43	0.29	0.18
Total Material Incorporation, output side (TMINCoutput)	0.54	0.24	0.15
Material Incorporation of Consumption (MINCofcons)	0.18	0.16	0.05
Food security			
Actual degree of food Consumption-Sufficiency (ACSfood)	0.98	1.15	1.08
Actual degree of food Self-Sufficiency (ASSfood)	0.67	.44	1.06
Potential degree of food Self-Sufficiency (PSSbare)	0.79	0.96	1.31
Actual Autarky (AAbare)	0.07	0.58	1.31
Potential Autarky (PAfood)	3.30	0.51	1.94

In all figures, the first two digits are significant.

good sign that such a simple indicator is able to pinpoint such environmental risk. Substantively, however, it paints a bleak future for Tat; Table 4.4 shows that 90 percent of Tat's export, hence cash earnings, comes from extraction and the food security indicators (discussed underneath) do not indicate an easy way out if this export would fall away.

Material intensity (MINT)

The group of indicators of material intensity (MINT) looks at the farming system at the input side. It is of special interest to check if the activity-based assessment of modes of production (see section 4.3) is confirmed by the intensity indicators of the rMFA. The intensity of imported material inputs (IMINTofAg) is by far the highest in Dy Abra; Table 4.4 shows that this is mainly caused by the large import of fertilizer. The pattern changes when the total intensity of agriculture (TMINTofAg) is taken. Jumping to close to 4 tons of input per hectare, Tat shows as the most intensive system; Table 4.4 shows that this is largely due to the high manure application. Nalang, which was estimated as the least intensive system, remains close to Tat, however. Table 4.4 shows that the 'input' of bamboo fencing to protect the cucumber fields against roaming cattle is the biggest component here; the intensity would drop to 0.76 tons per hectare if this input would be left out, bringing Nalang much closer to Dy Abra. The indicator of intensity of livestock keeping clearly shows the intensive animal husbandry of Tat, with a feed flow of almost 600 kg per capita. The importance of livestock in Tat appears in Table 4.4 with Tat being the sole village importing livestock feed and the one exporting most livestock per capita. Although there is more livestock in Dy Abra, these animals are not for marketing but for logging and plowing. Overall, the transitional sequence of Nalang/Dy Abra/Tat that was proposed in section 4.5 does not show up in all indicators. The rMFA intensity indicators, although useful in their own right, do not simply represent agricultural transition. Improvements may be possible by using a more subtle system of what flows to include, how to account for the weight of fertilizer versus that of manure, and so on.[26]

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[26] Based on approximate production functions it could be proposed to apply a conversion factor of 6 to fertilizer compared to manure. The result then is that Tat with a TMINTofAg of 4.46 tons/ha shows as much more intensive than Dy Abra (2.32 tons/ha) and Nalang (1.77tons/ha). Note also that the sequence of the villages is now the same as in the activity-based assessment.

Material incorporation (MINC)

The indicators of material incorporation in external markets (MINC) show that Dy Abra is the most incorporated, on the input and the output sides of both agriculture and extraction. The indicator for material agricultural inputs (MINCinputsAg), for instance, shows that Dy Abra depends for 98 percent on external inputs, and both Tat and Nalang for a mere 5 percent (caused by the high inputs of animal manure, which is a domestic product). On the output side (TMINCoutput), Dy Abra dominates the picture by its two large flows of exported timber and corn. Nalang remains at a low level of exporting only 16 percent of its net DE, with Tat following at 24 percent. The exports of Tat stem from a variety of physically demanding activities of extraction (e.g. bamboo, bamboo shoots, and timber) and swidden farming (e.g. canna, ginger) on the very steep slopes.

Food security profile

The last group of indicators concerns food security. Table 4.5 shows that the actual degree of food consumption sufficiency (ASCfood) is 1 or above in all villages. This consumption sufficiency is to be expected because no-one was seen starving at the time of the research. Differences in wealth expressed themselves in food quality rather than quantity, such as eating rice and fish in stead of bananas. Subtracting the food import to calculate the actual degree of food self-sufficiency (ASSfood), Nalang remains at almost the same level but the level of Tat plummets to only 0.44, showing this village's dependency on food imports.

'Potential self-sufficiency' (PSSbare) calculates self-sufficiently as a measure of short-term survival potential, assuming that people then would include all edible products ('bare calories') in their diet and stop exporting edible products. Table 4.5 shows that this does not make much difference for Nalang because the village does not export much and most of its food is rice anyway. Tat, with an indicator level of 0.96 in this circumstance, would be able to survive, basically by adding the canna, cassava and potatoes, now exported or fed to the pigs, to the human diet. The village would then loose much of its export income, however, which would be a threat to its bare survival in the somewhat longer run because money would lack to buy fertilizer for the rice fields. In Dy Abra, self-sufficiency does not rise much because its yellow corn is not counted as 'bare calories'; people have no technology to protect the corn from rapid decay after harvest. PSSbare would jump from 0.79 to 2.76, however, if its yellow corn would be added to the diet. People swim in an ocean of corn, so to speak.

The final two ('food autarky') indicators show what would and could happen if people would furthermore be forced to do without their external inputs in agriculture, especially fertilizer. As Table 4.5 shows, nothing much would happen in Nalang because it takes care of all its inputs domestically. Dy Abra however, fully dependent as it is on fertilizer, could then on the short term ('actual food autarky', AAbare) produce only a fraction of the food it needs, even if all bare calories are taken into account. Tat is intermediate in this respect, because of its intensive use of internal sources such as animal and green manure (see Table 4.4). The last indicator ('potential food autarky', PAfood) shows what happens if the villages would adjust their farming systems in order to survive without input and output markets. Table 4.5 shows that Tat hardly has any room left for such adaptation, because it already uses the majority of its available animal manure. The reverse picture is shown by Dy Abra; if the village would be able to use the animal manure that it discards at present, it could feed itself three times over even without fertilizer.

How different these villages are in terms of food security profile! Nalang quietly feeds itself and can continue to do so irrespective of external circumstances. Dy Abra is on a risky course at present but if it manages to keep up its soil quality under the heavy fertilizer load, it still has a very good option of less dependent, more organic agriculture (Hobbes and de Groot, 2003; Chapter 2). Tat is at risk in a deeper sense; it cannot do without food imports; without these it could survive only when eating all its roots and tubers and with that loose its pigs and much of its export; and it has already used up the option of intensive organic agriculture.

4.7   Conclusions and discussion

Taking an overall look at Table 4.5, we notice the strong contrasts between the three villages in terms of productivity, intensity, incorporation and food security. Nalang, with its relatively abundant land suitable for rice production, reaches its high production of rice per capita without high yields (tons/ha), without much external inputs, without great involvement in external markets and with robust options to keep up its basic (food security) independence. Dy Abra, on the other hand, focuses much on (timber) extraction and on non-rice agriculture that is fully fertilizer-based and export-oriented, with concomitant high indicator values on capital intensity of agriculture and market incorporation, which would result in an acute crisis if these markets would fail (a very low 'actual food autarky'). The high fertilizer application and high extraction

per hectare point at risks of unsustainability, undermining the soils that should be the basis of the 'organic option' expressed by its high 'potential food autarky'. Tat, finally, squeezed as it is in its narrow valley between very steep slopes, hence possessing neither Nalang's paddy space nor Dy Abra's space of rolling hills, appears to have used all its options already; it is hanging on with the highest intensity of agriculture, the highest production per hectare of agriculture and extraction, but low levels of food self-sufficiency and autarky. For Tat, the risk of unsustainability of its (forest) extraction and, invisible in the table, of its swidden agriculture too, spell a disaster scenario of hunger and out-migration.

In the remainder of this section, these results will be put in a broader context. First, the outcomes of the standard MFA indicators will be compared with those of other case studies. Then, one of these case studies will be used to discuss some of the rMFA indicators developed in this chapter. Finally, the relation between MFA and the more problem-oriented style of doing environmental science is explored.

Indicators in context

Table 4.6 shows a comparison with other cases and societies in terms of the two most important Eurostat MFA indicators. Trinket, studied by Singh and Grünbühel (2003), is one of the isolated Nicobar islands, India, depending mainly on coconuts. SangSaeng, studied by Grünbühel *et al.* (2003), is a small village in remote Northwest Thailand in which glutinous rice, gathering of NTFP and migrant labour are the mainstays of the economy.

The table shows that our three villages are quite comparable with Trinket island and SangSaeng, as well as with pre-industrial Austria. The great jump, obviously, is between all these rural societies and the industrial economies characterized in the last column of the table. This remarkable similarity of rural societies is worthy to note. It also leaves us with a problem, however; the DMI and DMC indicators are much too crude to indicate the wide variety in crucial indicators as discussed in the preceding paragraphs. They do not indicate what is actually going on *within* the broad category of rural economies. As long as isolated Trinket, independent Nalang, incorporated Dy Abra and constrained Tat have comparable DMI and DMC indicators, we obviously need more fine-tuned indicators.

On a more detailed level, the case of Trinket illustrates the perennial problem of 'sand in MFA'. Trinket has a sand and gravel quarry of which most of the products are exported to a neighboring island. These

Table 4.6   Direct Material Input (DMI) and Direct Material Consumption (DMC) indicators of various economies, in tons per capita per year

Indicators	Dy Abra	Tat	Nalang	Trinket	Trinket without sand	SangSaeng	Austria 1830	Industrial Economies
DMI	5.7	5.4	3.0	6.2	2.7	4.4	5.5	20
DMC	3.1	4.4	2.6	3.8	2.6	3.6	5.5	16

The figures of Dy Abra, Nalang and Tat differ somewhat from those in Table 4.4 because wood now stands at a 15 % water content, equal to the other cases. *Sources:* for Trinket: Singh and Grünbühel (2003), for SangSaeng: Grünbühel et al. (2003), for Austria 1830: Krausmann (2001), and for industrial economies: calculations made by Singh based on Mathews et al. (2000) and Schandl and Schulz (2000).

flows are so large that they greatly influence the indicators. Table 4.6 also gives the figures for Trinket without sand. We then see that the island falls from the top to the bottom rank in DMI and DMC terms in Table 4.6. It is essential to take great care of how to treat such large and non-biomass flows in the MFAs of rural economies and to keep them separate from biomass flows. In all rMFA indicators developed in this chapter, no sand flows are taken up. This assures good comparability with any rural village.

The productivity and intensity indicators of Table 4.5 may be compared with many of such figures worldwide. It may be significant for Tat, for instance, that rice productivity in the nearby Red River Delta, with 5.2 tons of milled rice per ha in 1994 (Cuc and Rambo, 2001), is about 80 percent higher than in Tat. The figure of Tat's intensity of livestock keeping, with approximately 1,150 kilos of feed and fuel inflow per household member in pig-owning farms per year (since some 50 percent of the households in Tat had pigs), may be compared, for instance, with that of factory pig farms in the Netherlands that run at an average material intensity of about 200,000 kilogram per household member per year (consisting of compound feed only).[27] The sensibility of such comparisons depends much on the research context, however, and these issues will not be explored further here.

Rather, we will take a look at the indicators of material productivity (MPROD), material incorporation (MINC), material intensity (MINT) and food security in discussion with Singh and Grünbühel (2003) who provide a multitude of valuable information on Trinket island but fail in the analysis of the transition, incorporation and dependence of the island.

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[27]   This figure is based on Landbouw-Economisch Instituut (LEI) en Centraal Bureau voor de Statistiek (CBS) (2000).

Transition is defined by Singh and Grünbühel as a major shift from one metabolic regime to another[28], and Trinket is said to have gone through a transition when during the 1950s the trade with the outside world changed from an exchange of coconuts and forest products against rice, sugar, clothes etc. to an exchange of processed coconut (copra) against the same products. This flow is 130 kg of copra per capita per year at present. This has certainly led to some changes in the island's metabolism, but would it also show up in the rMFA indicators? Singh and Grünbühel do not provide specific information here but as a general pointer, we may calculate the total copra flow (130 kg times the population of 399), divide this by the total area of the island (4000 ha) and arrive at a production indicator of 0.013 tons/hectare/year. This is not fully comparable with the TPRODofExtr indicator of Table 4.5 but if we do so nevertheless and notice that the figures of the three villages lie between 1 and 3 tons/ha/year, it may be concluded that the metabolic shift in Trinket is not likely to have been 'major'. A second pointer is when we take the total DE of biomass per capita of Trinket (2300 kg/cap/year) that compares well with total DE of the three villages (TPRODofAg plus TPRODofExtr in Table 4.5 lies between 2900 and 5600 kg/cap/year). How could a flow of 130 kg/cap per year indicate a major shift?

With respect to issues of incorporation and dependency, we may notice first that Trinket island imports only very little inputs for agriculture or extraction. With that import at 40 kilograms per capita (fuel) and a DE of 2300 kg/cap, Trinket has a level of material incorporation at the input side of less than 0.02, hence at the same very low level as Nalang and very much lower than Dy Abra. On the output side, the export of copra results in a degree of incorporation (TMINCoutput) of about 0.06, thus much lower than all three villages of this chapter. Only the indicator of the material incorporation of consumption (MINCcons), at the 0.23 level, is higher than of the three villages. This figure is caused by that the inhabitants prefer to eat imported rice, flour and sugar instead of native foodstuffs. It remains quite unclear, however, how Singh and Grünbühel (2003) can say that this lone 0.23 'strongly indicates Trinket's dependency on the industrialized world'.

A true dependency of Trinket is not visible either in the food security indicators. If we would assume that the present 'actual degree of food consumption sufficiency' (ACSfood) of Trinket is around 1, 'food self-sufficiency' (ASSfood) would drop to approximately 0.77 if the import

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28   I leave aside here that in section 4.1, transition is also defined as a shift from a subsistence to a non-subsistence society which, as said, is a different issue altogether.

would fall away, and rise again if people would change their diet (PSSbare). 'Actual food autarky' (Aabare) lies at the same level because the island hardly imports any agricultural inputs. If people would use their internal animal manure source (156 kg/cap per year) for farming, and/or would return to their native extractive foods, they would realize their 'potential food autarky' without food shortages (PA >1).

In this analysis, Trinket shows up as a community that changed its export from a few kilograms of raw products to a few kilograms of copra in the 1950s, without thereby arriving at any level of intensity, incorporation or dependence comparable with the other villages studied here. If any sequence of transitions may be discerned in the data, Trinket is at the first step in a sequence of Trinket/Nalang/Dy Abra/Tat. For real incorporation, Dy Abra may be looked at. For real dependence, Tat is the exemplary village.

The general conclusion here may be that for an MFA-based insight in any village's position with respect to grand issues such as transition, globalization and dependence, the village should be assessed, comparatively with other villages, in terms of a whole set of adequate indicators, such as those of rMFA.

MFA indicators and environmental problems

In the previous sections, environmental problems such as land and forest degradation have been hinted at a number of times, based on the rMFA indicators. The indicators cannot do much more than that; they do not themselves express environmental problems.

In this context, it is relevant to note the distinction between MFA and similar system approaches on the one hand, and the more directly problem-oriented approaches in environmental science on the other.[29] The latter allow for an interdisciplinary analysis, explanation and solution of problems of land degradation, deforestation, pollution, biodiversity loss and so on. Although these approaches have specific limitations[30], they can bring us much further into causes and solutions than MFA can do. Starting out from the concrete human activities that generate the problem (say, growing corn or logging), the analysis and confrontation of chains of effects and chains of norms bring us to identify victims and

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[29]   See, for instance, the Problem-in-Context framework of De Groot (1992).
[30]   Two limitations of problem-oriented approaches are that they only 'work' when a specific environmental problem is present, and that they do not easily add up to more theoretical insights.

the concrete influence of (policy, advocacy or local) values. Moreover, the causal explanation of the concrete activities may identify the 'primary' actors that decide over these activities, as well as secondary and tertiary actors that influence the primary actors, linked in causal chains of power that may run up to government or World Bank policies. Other elements of such a 'Vaydian' (1983) or 'Action-in-Context' (De Groot, 1992) analysis lead to insight into other (economic, cultural) factors explaining the problematic actions; see Chapter 3.

The problem-oriented analogue of MFA is Substance Flow Analysis (SFA) that focuses on specific problematic (e.g. toxic or eutrophicating) flows rather than the aggregated bulks of MFA.[31] Because of the specificity of the flows in SFA, they may be connected with concrete actors and actor-based explanations and solutions. Following this line of reasoning for local MFA studies, Hobbes et al. (2007; Chapter 3) have linked MFA to problem-oriented analysis by identifying one or more non-aggregate material flows (e.g. the flows of NTFP or swidden products) as 'problematic flows'. These problematic flows were then explained by putting them in their economic, political and cultural context by means of the Action-in-Context framework.

This connection of MFA with actor-based explanation of specific flows adds social and policy-relevant knowledge to the MFA and it provides MFA with a much-desired link to the social sciences (Duchin and Hertwich, 2003; Lifset and Greadel, 2002). For the present rMFA (and maybe for other MFA too), however, it would be much better if such explanations could be connected to the aggregated indicators, instead of to non-aggregated flows. Explaining, say, incorporation may be a much more relevant business than explaining, say, corn. Systematic theory building of local 'Indicators-in-Context', requiring a thorough connection with bio-physical, economic, political-ecological, cultural and geographical theories of land use, has not yet started, however.

General conclusions

Material Flow Analysis remains 'only material flows', hence without containing economic, political and cultural elements. This leaves a world to explore: linkages between MFA with cultural theory to investigate the connections between culture and material economy (Milton, 1996), linkages with time studies to form a more complete 'integrated

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[31]   The problem-oriented character of SFA may be read in the titles of its publications such as "Nitrogen Pollution in the European Union – Origins and Proposed Solutions" by Van der Voet et al. (1996).

analysis' of the local economy (Giampietro, 2004), linkages with actor-based explanations to put the material flows in their social context (as discussed above), linkages with farming systems analysis that might bring many more data within the reach of MFA studies (Pfister, 2003), linkages with bio-physical data to assess the sustainability of extractive and agricultural flows, to mention only some. In order to walk such roads with success, however, local MFA proper needs a stable basis, as the present chapter has aimed to contribute to, especially concerning the typically rural activities.

The chapter has focused painstakingly on the development of a precise and adequate system of flow categories and aggregated indicators for the MFA of rural communities. The indicators allow for comparisons with national-level MFAs but are geared especially towards quantifying the community's relationship to issues of productivity, transition, incorporation (linked to economic globalization), food security and dependency. The empirical results of the communities in Vietnam, Laos and the Philippines show that, contrary to the standard MFA indicators, rMFA has the capacity to bring great differences between the villages to light, not only of the relatively emergent features such as the productivity of agriculture and extraction but also of the deeper phenomena of transition, incorporation and food security risks. A review of data from Trinket island has suggested, additionally, that the quantification generated by the rMFA indicators facilitates a more critical and precise characterization of a community in terms of these phenomena than standard MFA and a qualitative discussion can do.

As it stands, the rMFA system of categories and indicators developed here allows for the construction of fully integrated databases where any change in raw data immediately results in changes of the indicators. In structure and nomenclature, the system is flexible; flows may be made more explicit or more aggregated, indicators may be dropped or added without raising confusion, e.g. adding the food function of livestock in the food security indicators of nomadic societies. Thus potentially, the rMFA system may become a platform for other scholars searching for cross-national comparison and valid insight.

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