social ecology vienna iff
ALPEN-ADRIA UNIVERSITÄT KLAGENFURT

SOCIAL ECOLOGY WORKING PAPER 120

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LOCAL STUDIES MANUAL

A researcher's guide for investigating the social metabolism of local rural systems

ISSN 1726-3816

März 2010

Simron Jit Singh, Lisa Ringhofer, Willi Haas, Fridolin Krausmann and Marina Fischer-Kowalski (2010):

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Social Ecology Working Paper 120, Vienna

Social Ecology Working Paper 120
Vienna, March 2010

ISSN 1726-3816

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LOCAL STUDIES MANUAL

A researcher’s guide for investigating the social metabolism of local rural systems

Contents

1. Introduction: The purpose of the manual

This manual provides concepts, methods and variables to describe the biophysical features of rural local systems. Based on the paradigm of social metabolism, we provide a framework for conceptualising and operationalising society-nature interactions for a sustainability analysis at the local level. In other words, the manual offers a systematic understanding of the environmental relations of local communities in terms of their dynamics and metabolic profiles. The emphasis here is on the 'hardware' (biophysical elements) side of the social system, and not so much on the 'software' (cultural elements). This distinction is based on the premise that social communities are not only cultural entities and systems of communication, but also represent biophysical realities in the sense that they draw materials and energy from the environment in order to maintain or reproduce themselves and their (man-made) artefacts. This throughput of matter and energy is determined for any given social system by the resource base, the mode of production, available technology and lifestyle. They together determine a social community's sociometabolic profile.

Looking at biophysical flows is not entirely new. Scholars coming from research traditions such as cultural/ecological anthropology and agricultural economics have conceptualised societies as socio-ecological systems organised around a flow of matter and energy with varying goals. For example, looking at the energetic return upon investment to show the efficiency of indigenous systems as well as to illustrate the dynamic equilibrium of such systems regulated by culture (Rappaport 1968, 1971), or studying the subsistence base of local systems vis-à-vis trade with other societies (Ellen 1979, 1982, 1990), or in gaining a systemic understanding of agricultural systems with land, materials, energy, and labour time as interactive variables (Rambo & Sajise 1984, Spedding 1988, Bayliss-Smith 1982, 2004, McNetting 1993). However, in the context of ecological sustainability, analysing biophysical flows have gained renewed relevance and are further developed through interdisciplinary efforts within human/social ecology and ecological economics, both theoretically and operationally (Fischer-Kowalski & Haberl 1997, Giampietro 2003, Fischer-Kowalski & Haberl 2007a).

Apart from a theoretical introduction, this compendium provides tools to capture biophysical constraints and opportunities which may serve as guidance for understanding the potential impact of system interventions Taking the functional interdependence between scale levels into account, such interventions may occur at the local level itself, or at higher system levels, and often have unintended side effects as we demonstrate in some of our case studies. On the other hand, research on the rural base provides first hand insights into the food producing system of a national economy. It allows seeing how rural communities organise their biophysical flows to sustain themselves and, to varying degrees, provide produce for society at large, and eventually the world market. Methodologically, this manual is the resume of a research tradition at our Institute during the past ten years. It pulls together the conceptual and methodological insights and experiences of several scholars who have engaged in local studies research in different parts of the world and varying contexts.

Pioneer work in this research tradition was done by Lyla Mehta (Mehta et al. 1997) on a community in an area later to be submersed by the Narmada dam in India. Subsequently, collaboration with scientists from the Amazon region (Brazil, Venezuela, Columbia and Bolivia) helped to further develop the methodology (Amann et al. 2002; Grünbühel 2002) and refine it with an in-depth study of a community in Thailand: Sang Saeng (Grünbühel et al. 2003). Another European funded research programme "South East Asia in Transition" (with partners from Laos, the Philippines, Thailand and Vietnam) provided us with comparable data sets to better understand the notion of transitions in local rural systems (Schandl and Grünbühel 2005). Trinket Island, part of the Nicobar archipelago in the Bay of Bengal, was studied by Simron Jit Singh (Singh 2001; Singh 2003; Singh and Grünbühel 2003). Lisa Ringhofer, as part of her Ph.D., provided another in-depth case from Bolivia (Campo Bello), fuelled in part by her engagement in improving on her professional development work (Ringhofer 2007).

Hence, the following chapters provide a step by step guide for researchers to undertake a local study, starting with conceptual clarifications, choosing an appropriate unit of analysis, defining system boundaries and identifying relevant biophysical variables and domains. Chapter 4 and 5 explain how to generate biophysical data in the field as well as compute relevant headline indicators for a sustainability analysis. Researchers following this manual will create a dataset for local socio-ecological systems that can be compared to other case studies following the same standard protocol. Templates (as excel sheets) are provided to structure the key data that needs to be collected, and the indicators to be based upon them.

So this manual ultimately provides a common framework within which you can place your own local study in a fashion comparable to other, similar studies. Such a common framework, however, cannot consider all possible details or regional idiosyncrasies; it only provides overall methodological and conceptual guidance. It cannot replace case study specific data; what data in each case need to be recorded depends on the specific focus of your own case study and the research questions to be addressed.

In the end, this manual ought to spur your interest in doing such a local study, and facilitate its planning. Undertaking a local study can be a thrilling experience not only on an intellectual level, but also personally. It is an opportunity to plunge into another culture, and be intimately engaged for months at a stretch. There are several challenges worth taking: the challenges to be accepted, to overcome cultural obstacles and initial frustrations, to firmly establish legitimacy for being at a study site, and the challenge of engaging the local population in your endeavour. In the end, it is a process of discovery, not only of the system under investigation, but also of your self; one culture against another juxtaposed.

BOX 1

"It was not easy to make contact with the people on Trinket. I had the impression that the Nicobarese avoided any eye-contact with me. Only the children seemed amused at my presence and constantly giggled when I smiled at them. During the day, I would simply wander about the village watching people's activity and asking questions. Replies were terse and showed no empathy…My constant measuring and weighing of food and materials became a source of amusement to the people. Yet it seemed that they avoided close contact with me for fear of questions. It seems that the people now like me and have gotten used to my presence, but they are scared of my volley of questions. They have to think about things they never thought before…Martin is making copra. My questions confuse him. They are a burden. How many coconuts? How much firewood? He refuses to say anything; simply nods. After one hour of counting and weighing, I get answers. But I have to observe Martin for three days to know more precisely the entire process" (from the field journal of Simron Jit Singh, 2000).

2. The conceptual and methodological base

2.1. Sociometabolic regimes and transitions

When a society interacts with its environment, it does so by the (sometimes unintended) exchange of material and energy and (intentionally) by means of applying certain technologies and labour in order to increase the utility of elements of the natural environment for itself. These activities generate impacts on the environment to which societies then have to respond. It is in fact a co-evolutionary process, as societies become structurally coupled with parts of their environment, leading to a situation in which both systems mutually depend on, influence, and constrain each other. This situation is maintained by a particular way a society interacts with certain natural elements - or, put differently – certain exchange relationship of matter and energy between the social and the natural system (for more detail, see Fischer-Kowalski and Haberl 2007). These typical patterns of biophysical interaction between the social and the natural system which may remain in a more or less dynamic equilibrium over long periods of time, we call *sociometabolic regimes*.

In the broadest sense, sociometabolic regimes in world history correspond to the human modes of subsistence (see, for example, Boyden 1992; Gellner 1988), such as the hunter and gatherer regime, the agrarian regime and the industrial regime. Beyond a historical reading, these regimes share, at whatever point in time and irrespective of biogeographical conditions, certain fundamental systemic characteristics. These characteristics take the form of specific sets of resource use, the use of land and labour, demographic and settlement patterns. Each regime is characterised by a certain *metabolic profile* that relates to a certain set of impacts upon the environment (Krausmann et al. 2008, Fischer-Kowalski & Haberl 2007b).

Historically, changes – or *transitions* - from one regime to another have been so incisive that they are referred to as revolutions: the Neolithic Revolution from the hunting and gathering regime to the agrarian regime, and the Industrial Revolution from the agrarian regime to the industrial regime. As to 'why' these transitions occurred in world history, we draw from Sieferle (1997; 2001; 2003), who is considered the founding father of the *theory of sociometabolic regimes*, the claim that a change in the energy system lies at the core of each sociometabolic transition.To Sieferle, the hunters and gatherer regime, as there is no deliberate intervention in transforming land cover (e.g. through farming techniques), has to be considered as an 'uncontrolled solar energy' system. For hunters and gatherers, the only sustainability threat they are exposed to is in the overexploitation of key natural resources. Agrarian societies, on the other hand, can be characterised by a regime of 'active or controlled solar energy utilisation' as they intervene in the process of solar energy conversion by means of biotechnologies (forest clearance and creation of agro-ecosystems) and mechanical devices (e.g. wind and watermills). The most pressing sustainability threat for this regime is coping with population growth rates that may be exceeding the productivity growth rates of agro-ecosystems (soil fertility). The presently dominant industrial regime, dating back less than three centuries, is based upon the exploitation of fossil fuels. Its sustainability is threatened by the limitations of its fuel resource base, on the one hand, and the transformations it prompts in various natural systems – such as, most prominently, the world's climate system. This regime relies predominantly on non-renewable material and energy resources. Change – another transition - is therefore bound to happen. In this sense, it is high time for searching transition pathways towards another sociometabolic regime that builds on sustaining society-nature interactions with a lower burden for the environment.

To analyse the specific dynamics of society-nature interaction, two conceptual tools are applied: *social metabolism,* on the one hand, and *colonization of ecosystems,* on the other.

Social metabolism: although the term metabolism originates in biology and ecology, the metabolic idea has been taken onto another level to describe the interaction of human societies with their natural environment. The concept is based on the premise that any social system not only reproduces itself culturally but also biophysically through a constant flow of materials and energy with its natural environment as well as with other social systems. The size of flows is intricately linked to the biophysical stocks of the social system and determined by the sociometabolic regime it belongs to: every sociometabolic regime has a different metabolic profile, i.e. quantity and quality of materials and energy used.

Colonization refers to a society's deliberate interventions into natural systems in order to render them more useful. Colonizing strategies are intrinsically linked to the exchange of energy and matter and depend on a society's technologies, knowledge base and cultural programmes. The larger the population and the larger its metabolic rates, the more ecosystems need to be colonized in order to maintain this metabolism. But for the colonized state of ecosystems to be maintained, societies have to organise a continuous input of human labour (and typically also energy and materials). Thus a social system's colonizing activities are closely related to the amount and quality of human labour they directly or indirectly (by producing and maintaining technologies) require. The more a society modifies its environment, the more metabolic returns it may expect, but the more efforts it has to expend to keep the relevant natural systems in the desired state – and this may create the need to invest even more energy and working time. Besides, colonizing interventions are interventions into complex systems – there is never full control and there are always non-anticipated surprises and risks which have to be counterbalanced by engaging in further risks. Thus, the colonization concept tries to capture the co-evolutionary dynamics that is unfolded by any kind of society-nature interaction. This means that even in the most apparently 'frozen' and 'static' traditional socio-ecological system every observable present state has to be viewed as one moment in a continuous reproduction and potentially transformation process.

2.2. Linking social metabolism with functional time use

Human time has various metabolic characteristics. To start with, human time is "created" by demographic reproduction. The higher demographic growth rates, the higher the growth rates of human time available to a social system. The higher the individual's life expectancy, the higher the available time per human life. Human time is a limited resource but – in the short run - evenly distributed among the members of a social system: everybody has 24 hours at his/her disposal. Especially in traditional social systems, the metabolic exchange relations between the people and their natural environment are coordinated by certain time norms (e.g. sexual division of labour) that are responsible for the functioning of the society. How human time is used, therefore, serves as a key to understand the social metabolism of a society. At the same time though, each human lifetime hour (from sleeping to wage work) can only be sustained through a certain metabolic input (matter and energy). A society's failure to supply these inputs will lead to major tensions, and specific solutions need to be found (see Fischer-Kowalski et al. forthcoming). These solutions may range from seasonal migration to demographic growth restriction measures and often do not go without social conflict.

How can we then establish the link between human time and a society's interaction with its natural environment? The answer is through human labour time. In traditional societies, every kind of interaction with the environment is mediated by the use of human labour (Krausmann 2004). For hunters and gatherers, for example, human labour is merely applied to meet direct subsistence needs. If the amount of labour time available does not suffice to satisfy the metabolic needs of the population, people will starve, social groups will fall apart and members will try to migrate to more productive environments. At the same time, as only human labour is invested in the interaction with nature, the extent of human labour time is directly instrumental for impacts on the environment. Increasing this labour time (by hunting and gathering more) beyond a certain threshold will tend to deplete the food base of the society. Working time in hunting and gathering systems therefore tends to be low (see, for example, Sahlins 1972) particularly for the reason that they do not colonize terrestrial ecosystems. In agrarian societies, working time tends to be higher but strongly differentiated by season and class (upper classes are freed from subsistence work). Agrarian development is intricately linked to more work per unit area in order to obtain more agricultural output for feeding growing population numbers (see Boserup 1965; 1981).

Concerning industrial societies, we need to distinguish between different phases. The first phase of the Industrial Revolution there is an increase in working time. The second phase reduces the demand for human labour; as fossil fuel based technologies substitute much of the labour input required. Thus, under the industrial regime, we no longer observe a direct link between the system's disposable labour time and its impact upon the environment (see Fischer-Kowalski 2007).

With human time use we follow the same systemic logic as with material and energy metabolism. On the one hand, we treat human time as a key resource at the system level; the 'stock' of available time depending on population size and reproduction. Concerning the 'flows' of human time, we distinguish between flows serving four functional subsystems that each need time for their reproduction: the person system, the household system, the community system and the economic system (for more detail, see section 3.5). Such a systemic analysis provides a clear picture of the amount of labour time available in the *whole* local social system, thereby aiding our understanding of the specific *opportunities* and *constraints* a society faces in its interaction with the natural environment. At the same time, analysing the time invested in each of the functional subsystems according to age and gender tells something about the functional differentiation and inequities within the social system, the 'social burden' a society (or some of its age/gender subgroups) is bearing.

The three concepts of *social metabolism*, *colonisation* and *time-use* are operationalised using what we call the 'Material and Energy Flow Accounting' framework, abbreviated MEFA. It is a toolkit to analyse the specific dynamics of society-nature interaction, or in more specific terms, the exchange relations of material and energy flows between a social system and its natural environment. Time use entails human population in its stock category, and reproduction rates, life/labour time in its corresponding flow category. Within the local studies, the MEFA toolkit gives a detailed metabolic profile of the system under discussion, an analysis of the feedback loops shaping both the social and the natural system, and a clear indication of the biophysical limitations the system is currently facing (in terms of material, energy, land and time constraints). Thus, the MEFA framework is characterised by three interrelated sets of relations that are compartmentalised as stocks and flows (fig. 2.1):

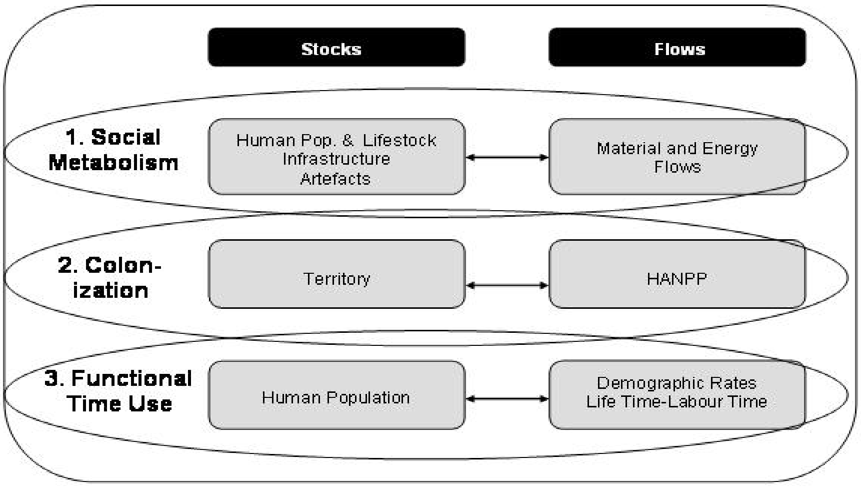

Figure 2.1: The MEFA framework

2.3. Scale interactions

Today, even in the remotest corners of the world you will hardly find a society that still lives an autochthonous, isolated lifestyle. Every local system, in one way or another, actively interacts with or is at least influenced by outside (economic or political) social forces. This is why you have to look at the different outside influences upon the local system you are observing. So when you are in the field, you should have in mind the following possible interventions from higher scale systems, as these are most likely to have an impact on the metabolic profile and social dynamics of the local system under observation and 'disturb' the ideal-type profile of the local sociometabolic regime:

- **Provision of services**: the provision of *medical services* is likely to have an impact upon demographic dynamics. Women from Trinket, for example, willingly participate in the Indian sterilisation programme, and this is a major reason for their low population growth rate. Another common intervention is *educational services*. Or think of the provision of *legal services* from higher scales that help the people to defend their rights; you may find this particularly the case with indigenous rural systems.
- **Supply of fossil fuel based technologies**: even if the local system under investigation does not use fossil fuels, the industrial regime on higher levels often creates an impact, for example by building *transport infrastructure.* Once there is a road or a ship line, opportunities for marketing produce, buying commodities from outside, labour migration, or any other exchanges with the outside world will greatly increase, and this, in turn, will modify the local production and consumption patterns. Another, probably more direct impact on food production is the supply of fossil fuel based technologies. The provision of *technologies for agriculture* (e.g. machines or mineral fertilisers) may be part of larger scale development policies that create some kind of

‘hybrid’ of the local production system. A more indirect impact on food production may be triggered by changing cultural conditions due to the inclusion of the local system in an *electricity network* or the establishment of *cell phone, radio, TV and internet connections.*

- **Supply of specific aid and subsidies**: even if food aid, for example, is supplied under ‘exceptional’ conditions only (in the aftermath of floods or droughts), it changes the functioning of the local system. Your system may have developed its demographic patterns in a long history of periodic extreme events and hence ‘adjusted’ to such fluctuations. If the system now becomes buffered by outside intervention and population reproduction patterns remain the same, unexpectedly high growth may occur and offset the local carrying capacity, as may happen in Campo Bello (case study from Bolivia) . In the case of pre-tsunami Trinket, for example, the main produce copra used to be sold on a subsidised price that was far above the average world market price. At the same time, the community would receive subsidised diesel to run their boats to and from the marketplace where the copra was traded. In Trinket, we saw that these subsidies had a huge impact on both the local metabolic profile as well as on labour time patterns.
- **Economic and legal framework conditions**: world market prices may also influence the production and subsistence dynamics of your system (e.g. rise in global oil price). The same goes for legal legislation in the area of agriculture, natural resource use or conservation. Legal framework conditions may indeed have a significant impact on the general organisation and local subsistence conditions of your system under investigation.

3. Describing rural sociometabolic systems

3.1. The choice of an appropriate unit of analysis

In this section you will obtain an overview of how to choose a study area, delineate its system boundaries and identify the most relevant biophysical variables and domains. First you will be confronted with the choice of an appropriate unit of analysis of what we will term as ‘focal system’ in the following paragraphs. This is in fact a key decision to start with in any ‘local case study’ of the kind described in this manual. And these are the steps you should consider in order to take a viable decision:

- Make sure the unit of analysis chosen may duly be considered a ‘sociometabolic system’. This requires checking the potential unit of analysis against a number of theoretical considerations explained more in detail in the further paragraphs.
- Make sure which territory, which population and which other biophysical stocks (i.e. infrastructure, artefacts and livestock) ‘belong’ to the focal system. In other words, establish the system’s boundaries towards (a) other sociometabolic systems and (b) towards the (natural) environment. A proper definition of system boundaries is absolutely essential for any study of biophysical exchange processes. Depending on how the system boundaries are drawn, the empirical results will change. From the perspective of the focal system, both boundaries – those vis-à-vis neighbours or higher level authorities, and those vis-à-vis the environment - have to be reproduced and defended.
- Once the focal system and its biophysical stocks are defined, you may proceed to account for the flows associated with the respective stocks.

3.2. Defining the system boundary of the focal social system

Core point of reference for all kinds of analysis is the social system. Social systems are conceived as *hybrids*, a *structural coupling* of a *cultural* system with certain sets of *biophysical elements*. Our understanding rests on the notion that social systems need to reproduce themselves culturally (via communication, see Luhmann 1984; 1995) as well as biophysically. Social systems exist only as long as they reproduce themselves, and thereby also reproduce their boundaries. It is this very procedural focus that guides our thinking. Social systems can be differentiated laterally among each other (similar, analogue systems existing side by side), hierarchically (systems nested within one another as subsystems), or functionally (the very same elements simultaneously belong to various different systems that reproduce themselves in different ways). A social system’s boundaries are always defined/reproduced by the respective system itself via communication (what ‘belongs to it’ culturally and how this is to be handled) and biophysically via labour (which sets of objects are reproduced and maintained in a desired state, see the notion of *colonization*). All those sets of objects not reproduced culturally and biophysically do not ‘belong’ to the stocks of the system; they belong to the system’s (natural or social) environment.

Societies are a particular type of social system. In the social sciences, there is no clear consensus about the meaning of the term ‘society’, neither within the disciplines nor between them. In sociology, this term commonly refers to a social unit consisting of a population on a certain territory, integrated by cultural commonalities (such as a common language, a system of legislation or a currency) as well as by political commonalities including shared procedures of decision-making, ways to enforce decisions, shared mutual responsibilities, and a certain guarantee of care in the case of need (see, for example, Giddens 1989). While in sociology the idea of common governance (such as the modern nation state) is particularly important for the notion of society, cultural anthropology tends to stress the functional aspect of mutual interdependence and reproduction. According to the textbook definition by Harris, society is an "organized group of people who share a habitat and who depend on each other for their survival and well-being." "Each society has an overall culture", he adds, which, however, need not be uniform for all members (Harris 1987: 10).

In social ecology, we too have a distinct way of viewing society. We conceive of society as *a social system functioning to reproduce a human population within a territory*. This definition distinguishes society from other kinds of social systems (such as a firm, or a friendship network), but it does not necessarily determine the location in a hierarchy of social units of a similar kind (for example, household, local community, state, federal state, or the European Union). The scale level is not such an important issue as long as it is understood that one (smaller) 'society' may be part of a (larger) 'society'.

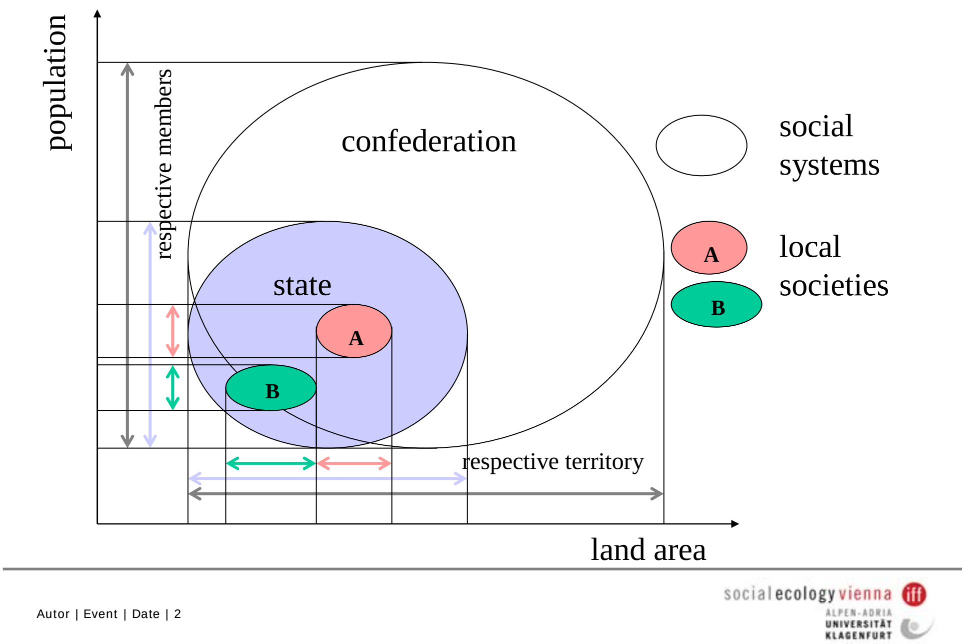

Figure 3.1. Society: a social system defining and linking mutually a member population and a territory

It is important to remain aware that society, such as other social systems, *functionally relates elements that are symbolic and transmitted by communication between humans ('culture'), and elements of a clearly natural origin and character, firmly subject to the rules of physics and biology ('population', 'territory')*. It should be clear that the population boundaries and the territorial boundaries of the social system are in no way 'natural', but culturally defined and reproduced by communication. This entails not only communication within the respective system, but also communication with other social systems, on the same level (such as neighbours) or on a higher or lower scale level.

Nr. of domains	STOCKS	FLOWS
1.	**Human population** (number, weight)	Natural reproduction Migration
2.		Life time / labour time
3.	**Livestock** (number, weight)	Energy: in-out Material: in-out [Water: in-out] Net primary production (NPP)
4.	**Artefacts** (weight; calorific value)	
5.	**Functional territory** (area)	

Table 3.1. A society's biophysical stocks and flows

We have already learned that the type and size of biophysical stocks 'belonging' to a society are defined culturally and by the investment of labour. Or more precisely, which people, animals and plants, infrastructure and durables, and which territory forms part of a society, is always a communicative process within the focal system, but also in interaction with other social systems. Admittedly, boundaries may sometimes be blurry and/or even contested. So we see that this distinction cannot simply be drawn by natural criteria (such as spatial parameters). Further down, you will find a discussion on how these distinctions are drawn for each stock.

Once we are clear on the biophysical stocks that belong to the focal society, the corresponding biophysical flows can be determined by 'natural' functionality: it is the sum total of all those flows required for reproducing the respective stocks. This means that all those energetic and material flows that are associated with the continued social use and reproduction of the respective stocks have to be considered. These flows always involve outflows to nature as well as to other social systems. This boundary crossing of flows brings us back to what we learned before: that we consider societies as hybrid systems that always, materially and energetically, function as open systems. Such a focus on a 'society' precludes the choice of a unit of analysis that may functionally only very loosely be interlinked, such as a watershed, a neighbourhood, or some kind of geographically defined region that does not constitute a social and political unit.

3.3. Functional (economic) territory

We define a *social system's territory as a geographical area that is under legitimate control of this particular social system.* This means that the area is specified in biophysical terms – it can clearly be positioned and mapped, but the delineations of this area are defined and reproduced communicatively, and defended also physically, by the focal social system (and eventually by other social systems it interacts with). So as a researcher, you are not free to choose territorial boundaries! The meaning of *legitimate control* may sometimes host ambiguities since legitimacy of territorial boundaries refers to a shared view among the members and a certain degree of practical use by the social system. At the same time, it also refers to the surrounding social systems (neighbours), who need to define their own territorial boundaries in a complementary way (often not without a certain degree of contestation). Usually, there is also a social system on a higher scale (a state, for example), which defines and reinforces the legitimacy of territorial boundaries (see also figure 3.1.). Hence, *legitimate control of a territory* always has a political and an economic component.

1. Legitimate ***political control*** refers to the existence of some governing body and its ability to set and sanction standards for social behaviour within the territory. How far these rights go, however, may vary substantially (basically depending on the degree of political power in the hands of the local system).
2. Legitimate ***economic control*** refers to the right to economically exploit the resources within the territory, the land / soil, the freshwater, the vegetation, the minerals, the rain and groundwater, the deer and the fish. Legitimate economic control can sometimes be a fairly complex issue. It may be limited in terms of resource use (for example, hunting of deer, mining for minerals or extraction of groundwater may be subject to a special permit granted by higher level authorities), or in terms of use of certain areas (for example, land stretches along riversides may belong to higher level authorities, or railways may be 'exterritorial'). These limitations are typically defined 'from above'. Conversely, private property rights constitute limits for common use at the system level, but may also imply territorial extensions 'from below'.

You might come across some more ambiguities and operational problems you will have to resolve *in situ*. With these theoretical guidelines in mind, you will have to search for specific solutions of your dilemma. Here are some ambiguities we have encountered in previous field situations:

- The focal society economically shares a forest with its neighbouring communities. Politically, the forest belongs to neither territory but both communities make economic use of it for hunting, gathering and/or collecting firewood.
  Possible solution: divide the common resource by applying different 'weights'. For instance, you may divide it according to the total area used by each of the communities involved, or by the number of people living in each of the communities. At the end of the day, the main point is logical reasoning!
- There exists a large cattle farm within your system's territory, which is politically defined as native, community-controlled land. The cattle farm, however, is privately owned and belongs to an international corporation. In terms of political control, the farm's land area is out of reach of the governing body of the focal society and does not contribute in any way to the functioning of the community (not even through tax payments). At the same time, the land cannot be accessed or used economically by any community members (such as for gathering firewood) – legally though, the privately owned land area is situated within the community's administrative system boundaries.
  Possible solution: exclude this land from the focal society's territory.
- The focal society has clear politically defined territorial boundaries. Nevertheless, members of this community own and regularly use stretches of land outside this territorial boundary (e.g. possession or leasehold of rice fields elsewhere), while members of other communities own and regularly work patches of land inside the (politically defined) focal society's territory.
  Possible solution: as the social system's metabolism refers to land a society (and its population) is entitled to use, economic control bears more relevance than the (somewhat deviating) political control. Hence, do include the land areas used outside the political territory, but at the same time subtract the land within the political boundaries used by outsiders.

BOX 2

“Admittedly, the definition of the territorial borderlines of Campo Bello was no easy undertaking and caused uncertainty, at least at the beginning stages of research. This was mainly because the official land titling process was still ongoing at the time of research and the village headman had revised his estimates of the community’s border upon my second visit in 2006. But there was light at the end of the tunnel, and with the support of oral statements by many locals and the fact that demarcation posts actually existed at some places (though hardly visible in the forest thicket), I was able to delineate the village boundaries upon return in 2006. Accompanied by a small group of local men and GPS technology, I was able to measure the distance between these demarcation posts. Once we had defined the territory the people of Campo Bello are entitled to exploit, things eventually became much easier.” (adapted from Ringhofer, 2007)

3.4. Human Population

We define a society’s population *as the set of people defined as legitimate members of that society*. Once more, it is the social system itself (and not an outside observer) that defines its members by a set of rules and practices. And again, you may find that the freedom to define this membership is limited by (for example legal) definitions of social systems on higher scale levels. Legitimate membership has three constituents that may - and usually do - somewhat deviate from one another: a political, an economic and a practical (presence/absence) constituent.

- ***Legitimate political membership*** refers to some (however limited) rights to participate in the self-governance of the social system in question. This entails active and passive voting rights for governance bodies, the right to participate in decision-making processes, the right to voice an opinion and eligibility for being asked. Such rights, however, in many cases are not a consequence of membership only, but also depend on other characteristics such as age and gender. Thus membership of the social system may first entail being a member of a smaller social unit (such as a family or a household) that is represented by someone with political membership rights.
- ***Legitimate economic membership*** implies some degree of entitlement to the use and governance of local resources (e.g. commons), economic support by the social system in case of need, but also an obligation to economically contribute to the social system (through tax payments, in public works, etc.).
- ***Factual presence*** relates to the amount of life-time actually spent within the community, or in other words, the periods of presence / absence in the community’s territory. Factual presence, on the one hand, implies a certain minimum use of resources (space, air, freshwater) regardless of the legitimacy of this use. Factual absence, on the other hand, can be associated with the economic contribution to the community’s resource base (e.g. through remittances), as well as with the consumption of community resources also during absence.

All this information becomes clearer once you have become more familiar with the dynamics of the community you are in. In a nutshell, the key questions are: which population is economically reproduced on the territory under consideration? Which population contributes to reproduce the social system by its labour and decision- making? Some examples from previous field experiences might help here. In the case of Sang Saeng (see

Grünbühel et al. 1999; 2003), for instance, seasonal labour migration is intricately linked to the village economy, as migrants supply their families with monetary remittances and take food (especially rice) from the village to their work location. These people and their foods, even though the food consumption takes place outside the community, were included in the metabolic profile of Sang Saeng. The issue of mobility is also discussed with the case of Campo Bello (see Ringhofer forthcoming), where the peripatetic nature of movement characterises the life of the indigenous village people. Paying short- and longer-term visits to others outside the community is in fact a deeply ingrained cultural feature of daily life. Methodologically, these members were still included in the stock account of the community as it is common practice for families to pack their canoes with nearly all their belongings including a variety of staple food stocks. Rather than living off other peoples' food resources, people tend to return home once their own food resources are depleted. Summing up: As here we deal with socio-metabolic analyses, the economic membership, i.e. the entitlement to and the actual use of resources, is the most relevant membership criterion.

3.5. Life time/Labour time

In this section we will take a closer look at each of the functional subsystems (person system, household system, community system, economic system) along which you will analyse the life time / labour time ratio at the system level. This classification does not differ much from what is found in sociological time use studies, but the interpretations we are interested in are somewhat different. Within local studies, we hope to attain a better understanding of the possibilities and constraints the system is facing in terms of its time resources. This empirical endeavour calls for a fine-tuned categorisation of activities which you have to adapt to the specific structure of the society you investigate. The main functional subsystems and their corresponding individual activity sets, however, do not change. Let us scrutinise them one by one.

The *person system* functionally serves personal reproduction and includes all those activities that are not subject to a division of labour. On the one hand, the person system holds all the functions that are physiologically necessary for a person's self-reproduction, such as sleeping and eating. These activities can neither be delegated to other members of the society nor 'outsourced' to specialists and are largely horizontally distributed in a population's time-budget. Apart from these basic functions for personal reproduction, the person system encompasses functions for extended reproduction, such as studying, leisure activities or idling. Breaking it down into single activities, the person system comprises sleeping (SL), eating (ET), hygiene (HY), rest and idleness (ID), leisure activities (LE), and study and education (SC). Hygiene may involve river bathing, the morning toilet or hair combing. The category 'rest and idleness' generally hosts periods of inactivity, such as lying in a hammock, resting in the shade or simply day-dreaming. Study and education entails the time spent at school and the time for doing homework, vocational training courses or studying for exams. Leisure, for our purpose of analysing rural local systems, refers to periods of deliberate self entertainment such as playing with children or pets. Here it is sometimes hard to draw a distinction to household activities (such as care taking of children) on the one hand, and communal activities (such as festivities, ritual visits to relatives…) on the other. It is up to the researcher to judge what he considers the main function of a particular activity to be.

The second functional subsystem is the *household system.* The household system takes care of those personal reproduction functions of its members that need or allow for collaboration and a division of labour. The household system is typically organised as an exchange of unpaid labour according to the social norms regulating age and gender roles in the local system. Time use for the household system contains the following sub-activities: care for dependents (CC), food preparation (FP), house building (HB), repair/maintenance work (MR), and domestic chores (D). Care for dependents involves child care as well as care for the sick and the elderly. Food preparation subsumes all activities related to food processing such as the disembowelling of game animals, the salting and drying of meat for conservation, the smoking of fish or the husking of rice. House building hosts the fetching and cutting of wood and other forest items for the construction of infrastructure, the gathering and processing of palm leaves for roofing, the weaving of door mats to serve as walls, etc. Repair and maintenance entails all activities required to sustain the physical household infrastructure: the mending of clothes or sewing, the manufacture of household artefacts such as fans, pots or floor mats, the fixing of the roof, etc. Finally, the activity set of ‘domestic chores’ considers shopping, the fetching of food and water, firewood collection, clothes washing, restoring order in the house and cleaning dishes.

On the next higher level of functional differentiation is the *community system*, which is the reference system for activities contributing to the reproduction of services on the community level, reciprocal relationships, social cohesion, culture and religion on the community level. It contains public sports and games (PL), visiting friends and relatives (VS), ceremonies and festivals (RI), communal work and political participation (PO). Public sports and games may include a football match or sports competitions. Visiting friends and relatives you may find a crucial activity in your system as traditional societies tend to pay particular attention to reproducing the social cohesion within their community. The same goes for ceremonies and rituals, which people might take extremely serious. The case of Trinket (see Singh 2003), for example, illustrates the cultural importance of such rituals and describes the elaborate preparation that goes into organising such events. The final activity set subsumes the time invested in communal work (e.g. school maintenance, clearing/sweeping public pathways) and political participation (e.g. political campaigning, council decision making). There is, as said above, some difficulty to draw a distinction towards “leisure” activities; the main criterion that may be used is the existence of a certain social expectation, a strong normative rule at times, that individuals do participate in these activities. If it is leisure only, they are completely free to choose whether they join an activity or not.

Beyond the confines of household and community, we deal with the *economic system*. For local studies, the time invested in reproducing the economic system is what we refer to as “labour time”. In general terms, the economic system implies and relies upon a social division of labour beyond the confines of household and community, and it usually involves monetary transactions. In subsistence societies, however, the functional equivalents of ‘going to work and bringing home a salary’ or ‘running a business’ are not so easy to identify. The choice taken for our purposes relies on the fact that the character of the activity itself is not so different whether it is done to supply the household directly with the respective produce (say, fish or corn), or whether it is done to supply (some of) the produce to a market, using the income achieved for further commodities. The economic activity includes all preparatory tasks for economic transactions (e.g. manufacture of working tools, repair of irrigation pipes, handicraft for subsequent sales), as well as directly productive work (e.g. harvesting, fishing, hunting). The following activities are distinguished: agriculture (AC)[1], hunting (H), fishing (F), gathering (G), trading (TD), wage work (W), kitchen garden (HG), manufacture of handicraft (MF), and animal husbandry (AN). For Agriculture/horticulture (AC), the range of activities included should reflect the entire agricultural cycle from land preparation to cultivation, weeding and harvesting of crops. Hunting (H) and fishing (F) should only reflect

[1] In some systems where you find an intended (and substantial) cash crop production component, you may calculate the labour time invested in subsistence and cash crop agriculture separately and account for it in terms of two different activities: subsistence agriculture (SA) and cash crop agriculture (CA). In local systems where only agricultural surplus is traded on the market, you should account for agriculture (AC) only.

the actual time spent in the activity, whereas the manufacture of hunting and fishing devices (bow and arrow, slingshots, hand-made fishing nets, etc) falls within 'handicraft' (see below). The time for gathering (G) may sometimes be difficult to measure since especially men do not necessarily engage in separate gathering trips but do gathering as a side activity during hunting expeditions. However, in many societies, women and children usually set out on specific gathering trips for seasonal forest foods or other forest items needed for the manufacture of artefacts. Trading (TD) may involve the bartering of produce or monetary transactions on the market. Wage work (W) includes all kinds of paid work, from short-term to more permanent placements. 'Kitchen garden' (HG) subsumes all activities related to the maintenance of the kitchen garden, from cultivating, watering, weeding and harvesting the local fruits or vegetables (remember that the processing falls under 'food production'). As mentioned before, the activity set 'manufacture of handicraft' (MF) entails both, the manufacture of tools for hunting, fishing or agriculture, on the one hand, as well as the making of items for direct market sale, on the other. Finally, animal husbandry (AN) should consider both, the direct (e.g. feeding or milking) as well as indirect reproductive activities (e.g. building and fixing stables, fencing, etc.).

Travel time should normally be added to the activity it is associated with (see also time use templates in the appendix). However, do not follow this advice rigorously if you feel that it may distort your actual aim. If, for example, you are interested in calculating the labour time per area (h/ha), then the inclusion of long travel times to reach the agricultural field may misrepresent your results. The same goes for calculating the productivity of hunting or fishing. In some cases, distances are quite negligible as fields or waterways are basically just a stone's throw away from the peoples' dwelling. In other cases, distances to productive sites may be much longer. So you see this issue may become quite a dilemma and we appeal to your own ingenuity to find solutions to your specific problem. Carlstein's (1982) book *Time resources, society and ecology* may become a useful companion along the way as he has given quite some thought to the issue of accounting for travel time in time use studies.

Finally, here is some general advice to you: you will know best how to distinguish your local system functions and the meaning certain activities have. If you feel the need for adding some sub-activities or simply rearrange some, then go ahead. In any case, most activities are quite fixed and don't need changing (e.g. sleeping will always fall within the person system), while others may do (e.g. in some societies, hunting may be regarded as a leisurely activity rather than a subsistence activity). The same might be true for fishing or work in the kitchen garden.

3.6. Other biophysical stocks

While you should now be clearer on the human population (stock) and the associated flows (time), we are now going to look at the other biophysical stocks to be accounted for: (1) livestock, and (2) infrastructure and artefacts.

Livestock

In order to decide on which livestock to include and which not, the following three key questions shall guide you: are these animals culturally defined as 'belonging' to (members of) this society? Is the reproduction of these animals deliberately and to a far extent controlled by (members of) this society? Is human planning and labour invested in their feeding, health and breeding? In conclusion, the key here is the investment of human labour into the control of animal reproduction. Operationally, this means that wild deer, for example, which does not belong to the society or some of its members, should not be considered as livestock.

It is important to be clear on which animals belong to the category 'livestock' and which don't, since only their material and energy requirements (feedstuffs) are counted as flows attributable to the social system (even if the animals graze in the wild). Also, the time invested for the upkeep of *these* animals only should be included in the economic time profile of 'animal husbandry'. The template at the back gives you a detailed overview of the livestock classification.

Infrastructure and artefacts

The definition of infrastructure and artefacts should also be guided by similar key questions. Are these artefacts culturally defined as 'belonging' to (members of) this society? Are these artefacts deliberately used and maintained by (members of) this society, and not just leftovers from historical human activities? Operationally, this may become quite a fuzzy endeavour, because the time frames of use and maintenance may be highly variable. On the one hand, artefacts that are typically used up or out of use within a year are considered as 'flows', not as 'stocks'. So these short-lived artefacts should not be included in the stock-account. Artefacts with a longer lifespan (such as buildings, bridges, dams, paved roads) may simply appear to 'be there' and be utilised, or might have received little or hardly any kind of maintenance for a long time. If this is the case in your system, remember that the cultural definition of 'belonging' or 'needed' makes the decisive difference. In contrast, abandoned structures (e.g. abandoned buildings which are no longer used) are not accounted for as artefacts, since they do not contribute in any way to the system's metabolic turnover. Fields or simple paths, even if they are regularly maintained, should also not be included in the artefact stock account. The same applies also to more complex field structures where natural systems have been massively reorganised by humans. One such example would be elaborate field terracing techniques (possibly though the stone walls stabilising these terraces that need periodic repair may be considered as infrastructure stocks).

Here is some general advice to you: be clear on the body of artefacts and infrastructure belonging to your system's stock account before you proceed to the accounting of flows. In order to follow the social metabolic logic, only the flows (materials, energy and time) required for the production and reproduction of these (previously identified) stocks are relevant for your biophysical accounting.

Plants

Following intensive discussions within the MEFA community, there was general consensus not to include plants in a society's stock account. This, however, is somewhat arbitrary since in many respects plants may be reproduced by society, both in the sense of planning and cultural definition, and in the sense of physical reproduction. Yet there are some good pragmatic reasons not to include plants in a society's socio-economic stock account: if plants were considered stocks, then the flows required to maintain their growth would also have to be accounted for. If this was the case though, one would have to include the uptake of huge amounts CO_2 and plant nutrients as an input, while crop harvests would present a flow within the socio-economic system - and this would clearly obscure some crucial characteristics of rural systems. There is yet another reason for excluding plants from a society's stock account: in practice, it is hardly possible to distinguish between plants that are 'reproduced by society' and those that just grow on their own device. The natural reproduction of plants is much more difficult to control than that of livestock.

4. Methodological guidelines by empirical domains

4.1 Introduction

In the preceding sections we have provided some general methodological guidelines to assist you in the design of a local biophysical study. Now we turn to methodological guidelines with respect to data collection and organisation. Depending on the specific research questions you want to address in your study, and the local biogeographical and socio-economic situation you will have to make decisions on which variables you want to consider, how you organise your data and which indicators you want to calculate. There is no standard way of doing this and we cannot provide a default protocol for data collection. We rather aim at describing a set of key variables at a medium level of aggregation which should serve as a common denominator for comparative analysis. The variables discussed in this section are all included in the excel template accompanying this manual and are used for the calculation of a set of important socio-ecological indicators (see section 5). Such a common denominator will naturally not be able to capture all issues relevant in a specific case study and aggregation always means that information is lost. Therefore, your case study specific dataset will most likely be much more detailed than the variables discussed here. Nevertheless, the information in this section will help you design your tailor-made set of variables and indicators appropriate for your study site and questions.

At the outset we can say that for undertaking local studies we depend on a variety of methods when it comes to data generation. The basic goal of social metabolism methodology is its applicability on all social scale levels and across time. While for nation states public statistics provide much of the data required, it is usually difficult to find existing official data sets at small scales, such as for a village or an island. It is common to find aggregated figures for larger areas comprising several villages that correspond to administrative units in a given context. Secondary literature (scientific or grey) may be helpful to supplement official statistics as well as your own data. While all this documentation is useful in several ways (such as for cross-checks between your own data for a village with that of the region), you still need to get more or less precise and disaggregated data on stocks and flows for the system under investigation. And the data you need for your local biophysical analysis - just think of the weight of building stocks, human artefacts and time use - you will more than likely not find readily available. To thus generate your own data, one needs to use a combination of established methods as well as ingenuity and creativity with logical reasoning on the field.

Before we go on to present some methods that have been successfully deployed, there are some general considerations that should be kept in mind. For estimating stocks and flows, it is important to differentiate between ‘elephants’ and ‘mice’. You are confronted with a large amount of variables but not all of them are equally significant. You should be careful not to spend most of your limited time resources to collect data on material and energy flows of little significance within the system (the ‘mice’), but rather concentrate on a limited number of significant flows (the ‘elephants’). An ABC analysis can help to find out what the dominant stocks and flows in your system are. In a first estimate, a very rough back of the envelope calculation can provide information of the size of different flows relative to each other. Begin your empirical work with the most important flows (these are often, but not exclusively, the largest flows in terms of mass) or flows of particular interest with respect to specific research questions or with respect to other variables. Then work yourself down to less significant variables.

For example, if the amount of hunted animals is small, but the time that is used for hunting is large, it might be useful to try to quantify the amount of hunted biomass. Besides direct measurements, there exist a variety of ways for how one can arrive at estimates: use measurements from other studies in similar contexts, design sampling procedures and extrapolate results to the entire system, use established factors for calculations, and engage in cross-checks and fine tuning of data using secondary sources.

Finally, never forget to carry a notebook with you on your daily rounds. We would even recommend two notebooks, one as your official field book for primary data, containing all your field jottings, diagrams, interviews and time-space-maps. The second notebook could serve more as a personal memo book and contain any peculiar observations, quirky notes, ‘off the record’ contemplations, and field diary entries. The advantage here is to keep the first and ‘official’ notebook fairly orderly and uncluttered with extraneous field notes.

4.2 Establishing contact

Undertaking a local study is an exciting journey both for yourself and for the people you are going to share a part of your life with. It likely will be a journey to a far-away world you may not be familiar with. Thus, besides the scientific endeavours, there is an additional challenge of bridging two cultures and being accepted by the community. It is a narrow path of wading through several layers of complexities: social, cultural, administrative and political. A successful study does very much depend on how the people perceive and accept you and allow you to witness their everyday lives; at times, a rather intimate process. In the end, it is usually a rewarding process and it may turn out that you remain connected to the region and to the people for the rest of your life in some way or the other. That is usually the fate of dedicated and passionate anthropologists. Local studies of social metabolism ask some different questions than cultural anthropologists, but the process of becoming part of the local community and the ability to sensitively undertake your investigations are similar. It is about taking off your own shoes and stepping into and accepting another culture and way of life.

All this requires a great deal of preparation. From looking up various sources of information about the region and the people, speaking to those who have been there, obtaining references, finding out the need for necessary permits from the local authorities, making a list of what you might need when living in a village where what is basic for you may be considered quite a luxury. Don’t forget to take some symbolic articles that give you a sense of home far away and some photographs of your life back home (home, family, friends, pets, landscape) to show it to the people on a suitable occasion. People open up when they see more of your context and become curious. When you do finally arrive, there is the need to make some important decisions. If you have not got a local contact (which could be the local leader, school teacher, nurse, etc.), then try to find a point of entry[2]. Usually, it is not a good idea to stay in a nice hotel or drive around in a hired taxi if you are visiting a poor region. It tends to distance yourself from the people and it would take much longer for you to be accepted. Sometimes being associated with the government may also be a disadvantage. So once you overcame the bureaucratic hurdles and have the necessary permits, try to remain neutral in your relationship with officials. Avoid favours such as the use of their guest house or a vehicle. It is necessary to be as modest as possible and to come as close to the lifestyle of

[2] In her field research with the indigenous Tsimane’, Lisa Ringhofer’s point of entry was the Tsimane’ Council. As the political authority of the Tsimane’, they had to formally grant permission on any kind of research that would take place in their territory. Also, they were helpful in the selection of a village and the general logistics and accompanied her to the community in order to formally introduce her to the villagers.

the people as possible. Eat local food, ride local transport, wear simple, make efforts to pick up some of the local language, and always smile!

Arriving in a village for the first time can be overwhelming both for you and for the community. It is important to respect the local leadership and hierarchy. You should not come across as a threat to anyone who can perceive you as one trying to change the order of things. It is important to establish you as a student or researcher who has no motive but to learn how they live and what their relationship to nature is. Show respect for their lifestyle and try not to give an impression of them being inferior in any way. It is you who wants something from them and not the other way round. And above all, do not raise expectations or make false promises - this can be very counterproductive. One should rather soon (but carefully) try to find out the dynamics in the community, such as internal conflicts, alliances, preferences and hierarchies. It is essential to avoid being stigmatised as being part of one group or against another. There is no real formula for this, but how you establish yourself as neutral with a sound relationship to the majority of the population requires reasonable social skills, diplomacy, and a good sense of dealing with human relationships and their dynamics. It is a risk one has to take but being cautious and self-reflective is certainly an asset. And don't forget to rely on your feelings!

BOX 3

"In the early hours of a clear September morning, Everisto from the Tsimane' Council and I finally took off on his motorbike to Campo Bello. Leaving behind the urban infrastructure of San Borja we followed a dirt road that slowly turned into a continuously more rugged and narrower forest path as we reached the banks of the Rio Maniqui. Upon reaching the first Tsimane' dwelling in San Antonio, a neighbouring community of Campo Bello, we were greeted with a friendly *Najjoi'* (good morning). Upon catching sight of us, passers-by would exclaim '*Hana mura mi*', where are you going? It is an expression that I learnt quickly, as it was of common usage upon any sort of casual encounter with others. We managed to move forward slowly on the back of the motorbike until the narrow forest trail suddenly gave way to the sprawling river… After reaching the other river bank, it was still a half-hour walk before reaching the community hut and the school premises, both of which somewhat represent the village centre. When we arrived, a couple of people had already gathered there, seemingly expecting the stranger (I later found that the Tsimane' Council had announced my visit via their daily radio programme). Everisto introduced me as a researcher who wanted to stay among the community members for the six months to come. After explaining the broad goals of my research, the villagers, though seemingly fairly indifferent to my presence, gave their consent to participate in the research. Shortly after, the local teacher, known by everyone simply as the *profe*, pointed to an old kitchen structure, a mere four-legged wooden shelter with no walls but a thick palm-thatched roof. There I could fasten my hammock. The building had long been abandoned; only its rooftop occasionally served as a resting place for poultry. A little later, Everisto embarked on his return to San Borja and I was left to my own devices" (adapted from Ringhofer, 2010).

After you have settled down, probably in some cheap accommodation nearby, or at a local inhabitant's home (after having made sure that this person is not controversial), take a walk around the village. You can learn a lot by just observing! How the people live, what they live from, what they own, how they go about their daily chores, what their main activities are, how the division of labour is organised, what the extent of land they use is and how they use it, etc. You need this time to observe and get a feeling for the system before you go about collecting data. In any case, it would be too quick to start questioning, measuring and weighing soon after you arrive. You might intimidate the people. So the first couple of weeks should be used to familiarise yourself with the social and the ecological system by mere observation, to establish rapport and get accepted before you pull out your scales, notebook and local studies manual.

4.3 Human Population (stocks and flows)

As mentioned before, the human population comprises the most important stock for any social system. We need to know the system size in terms of numbers, composition by age and gender, and weight, as well as flows in terms of births, deaths, and migration. It may be that demographic statistics for that area are available, but not necessarily. In that case, there is a need to generate ones own data. Having walked around the village for a couple of weeks, and becoming familiar with how things work, you would have already gathered an impression on how households are organised. They may be nuclear or extended. Try to find out through informal discussions what comprises a household for this society. Equating the number of families (as defined by marriage bond) with the number of households might be misleading, since you may well find two or three families living in the same domestic unit. At the same time, the number of dwellings is not an indicator either. In some societies, a household is a family system with their own kitchen, or a joint land holding. So there may be a cluster of huts with grown-up children and their families but if they share a common kitchen, or share the same piece of land for subsistence, it is considered as one household. Sharing of meals at other's houses (especially in the case of children) is common in traditional societies, so be careful not to double count. Other useful information is to find out how decisions are taken in the household, who is the head, how the division of labour is organised, etc.

It may be time now to pull out your notebook and take a census of the village, but carefully. Usually, in traditional societies people are intimidated when you take notes since they do not know how this information is going to be used, for or against them; for good reasons, of course. Once you are confident that you have established a good rapport with your research subjects, it may be a good idea to begin with a human census using the form attached with this manual (can also be combined with the livestock census by asking questions; we will come back to this later). The head count of a family is usually discussed with the head of the family. It may be difficult to get the exact age of a person as in traditional societies people do not keep record of birthdays. But with some discussions, this can be well estimated. In any case we need age groups by sex (0-5, 6-15, 16-60, >60). One can begin with a family tree of those living in the house; from the oldest person in the family one can go down to the youngest siblings, those married in and married out as useful information. Then try to estimate ages of these people in relation to each other. In difficult situations it might be useful to provoke your interview partner with questions of past events, or whether he/she was born before the neighbour's child, etc. New births and deaths are easy to record as they are likely to be within the frame of a year or two. This is important information for accounting for flows to which we shall now turn to. Before, however, once the stock account is established, you need to calculate the peoples' respective weight (in metric tons). You may literally weigh a small sample of residents (may be a fun event, especially for children) and extrapolate their average body weight onto the entire village population; or you simply resort to estimates.

Flows for a human population mean the number of births and deaths taking place each year, as well as migration patterns (seasonal, annual, permanent). This is a tricky issue. You may not have readily available statistics on this, but it is worth a visit to the local hospital or dispensary, the mid-wife or the church (if any). These usually have records of the births and deaths taking place in the village. For reproductive histories, supplement this data with local school records (teachers tend to be a good source of information about the whole community!), a recent municipal census as well as by asking each household the number of births and deaths that have taken place in the last one year and to whom (including infant mortality)[3]. From this one can calculate the population growth rate, the death rate, infant mortality, and the fertility ratio. To understand migration patterns, one has to ask if there are members of the family that work elsewhere, permanently or seasonally. This has to be taken note of, including information on what they take with them (particularly in the case of seasonal work) and what they bring or send back (in all cases). At this point it might be useful to deviate from the topic of census (your interview partner would be getting impatient by now; they are not used to sitting long hours and answering questions) and go into the socio-economics of migration. So to say, what the need for migration is, what are the benefits, how much income does it bring, is it prestigious, does it have an influence on the local society and culture in any way, how does this influence the introduction of new goods, social and cultural behaviour into the society and how is it received, and so on and so forth. Obviously, you have to show deep interest in the lives of the people there, and genuinely so, because if you do not, it is felt and you may not receive the answers with similar enthusiasm.

4.4 Human time use (flows)

By now, your initial rounds through the village and household visits have certainly provided you with first insights. You have surely gathered an impression on how life within the household is organised, and gained an idea about the age and gender allocation of labour. Generally, our methodology for recording time use is not yet as well elaborated as our methodology on social metabolism and land use, but there are basically two approaches to data collection: (1) self-reported assessments and (2) direct observation. Both methods contain a variety of sub-methods which you will best learn from anthropological literature such as Bernard’s (2006) detailed account of direct observation methods or Howell’s (1990) ironically titled publication *Surviving fieldwork* (again, literature from cultural anthropology can help a great deal in how to go about your investigations). But before you decide on which method to opt for, let us have a look at the pros and cons of each of these approaches.

Self-reported assessments, on the one hand, generally resolve most ethical issues, since the informant decides which behaviours to report and which not to mention. Another point in favour is its time-saving character for the researcher. One of the major drawbacks, however, is the problem of reliability as people tend to remember their own behaviour only selectively. This is not necessarily deliberate deception but a consequence of cultural models for the significance of activities. Especially when reporting on agricultural labour time, farmers may well underestimate the total hours invested in productive tasks. There are two reasons for so doing. (Particularly) male household heads may simply underestimate the involvement of children or elderly people in the productive process as, culturally, their effort does not get the same consideration as the labour invested by (male) adults. Also, as we have learned previously, people may have a different perception of the concept of labour and the distinction between working and non-working activities for them is not so clear. Also, think of the concept of a ‘working day’. Whereas in Western societies we may think of an 8-hour working day, traditional societies accommodate their physical working day around natural/seasonal cycles (e.g. work in the field tends to drop sharply when the midday heat becomes unbearable). In some cases, you may also consider the use of a time diary, which has a higher degree of reliability (obviously depending on how committed the informants are). But do remember the general constraints that come with it: the need for literacy levels and the

[3] In Bolivia, Lisa Ringhofer experienced that families tend to leave out newborn babies when asked about their number of off-springs. This, as she found later, was culturally motivated as newborn babies are not considered full household members and are hardly ever given names in their first year (in case they may not be strong enough to survive). Only when a baby seems fit for life, it is blessed with a name and becomes a fully integrated member of the family.

use of watches to record the duration of individual activities. Both aspects may be lacking in the rural system you work in.

BOX 4

Shortcomings from self-reported assessments: some facts to consider

In his time budget study in rural China, Pastore et al. (1999) note that their results – based on self-reported assessments only – may suffer from limited validity for two reasons: First because of a sensible involvement of children and elderly in productive activities – work carried out by both sub-groups does not get the same consideration as time invested by adult members. Second, in households were the opportunity costs are low (as this may be case in many traditional rural households), the distinction between working and non-working time is not always obvious.

In a study of rural women's time use and after having collected both kinds of data simultaneously, Scheper-Hughes (1983) found that women failed to report 44 percent of their work as recorded by direct observation.

Being a woman also has an impact on the information you obtain. (1) It limits your access to certain information; (2) it influences how you perceive others. An interesting anecdote comes from De Walt et al. (1998) who together with two other women spent months investigating the nutritional strategies in two rural Kentucky counties. Their informants never said a word about the use of alcohol in the community; only when a male sociologist joined them on one of their field trips, the local leader opened up and began to talk freely about the community values concerning alcohol use. He felt it would have been inappropriate to discuss the issue with women.

In order to overcome the shortcomings just discussed, *direct observation* in many cases provides a much more reliable picture. This research method can basically be done by either following the subject around all day or by using spot checks. It is about immersing yourself in the household/village dynamics and, in so doing, gain entry into the 'backstage' life of the social system. You will gradually learn about the meanings of different activities, intentions, events and situations. The drawbacks with this method concern mainly sample size and distribution. One issue is time distribution: are there strong differences according to the days of a week? Do your data account for the varying seasons of the year? Similarly, be also careful to achieve an appropriate sample. Samples have to be large enough to cover the different age/sex groups of the social system, different migratory backgrounds and household composition. Also make sure you also cover the various social strata of the society under consideration (if any). You may find the latter problem less prevalent in your society as many (predominantly indigenous) traditional societies have a rather egalitarian social structure. As a rule of the thumb, you should have 5-10 observed person-days for each age/gender subgroup (or any other group you consider relevant) in order to do reliable estimates for the group and (through weighing by demographic structure) for the community as a whole. Seasonal variation and rare events (such as longer sickness or extended festivities) have to be taken into account separately.

On the downside, direct observation may be seen as intrusive behaviour as you are basically 'shadowing' a person for a certain period during daytime. We appeal to your sensitivity on what is socially and personally 'acceptable' and what is felt as invasive behaviour. Spot checks, if culturally more appropriate, are indeed a good alternative to a day-long accompaniment of an individual person. The trick with spot checks is to catch a glimpse of people in their natural activities before they see you coming on the scene and before they have a chance to modify their behaviour. Data from spot checks also require good sampling and sophisticated statistics to be able to generate a comprehensive picture.

BOX 5

In her study of Campo Bello, Lisa Ringhofer (2007) had originally asked 20 people (mostly from befriended households) to be followed around for a 14-hour daytime period (six a.m. to eight p.m.), however, two decided to withdraw from the time study. In order to obtain information on the age groups now left out of the 14-hour shadowing, she decided to conduct additional spot checks and thereby arrived at two more full person-days. For this endeavour, a non-random person was selected, who was visited four different times throughout the same daily round, and discrete notes were taken of what he/she was engaged in for a 15 minute period each time. In so doing, a time allocation period of one hour could be documented. This sample method was then repeated for a total number of 14 active adults and 14 children, from which an additional 14-hour person-day could be derived. For toddlers and the elderly population (the latter was more apprehensive in participating in time use studies), she resorted to estimates which she cross-checked with interview data and general, but more informal, observation.

Simron Jit Singh (2003) opted for a different approach. In his study of Trinket Island, his time use account focused on labour time only. He recorded certain tasks (such as renewing a roof, feeding a certain number of livestock, or planting rice) repeatedly and in great detail: what kind of persons participated, for how long, and in which intensity. In order to arrive at system level data, the frequency of these processes across the year had to be estimated and used for weighing. Wherever possible, there was an effort to enhance data reliability with cross checks using interviews and metabolic data. For example: for how long do large groups go out for fishing every day (observation of samples); interview question: how much was the catch the last time you went fishing and how many people and for how long were you out at sea? How many kilogram of fish are being consumed annually (metabolic data)? Are both annual estimates congruent?

Hence, depending on the local context as well as on the nature of your research question, you will have to decide on the time recording methods you apply. What is crucial to remember though is that all methods are sensitive to the choice of season of recording and you will need a large enough sample to cover the various parameters (age, sex, social strata) prevalent in your studied system. Always make sure to enhance data reliability with cross-checks using interviews and other metabolic data.

When you are in the field, you surely will be confronted with different obstacles along the way. Here are just some which we have so far experienced in previous study situations:

- *Night time sampling* may be culturally inacceptable, seen as intrusive behaviour or simply too dangerous.
  Possible solution: resort to grounded estimates for the remainder of time not covered by direct observation, you may also have the chance to observe night time behaviour from afar (see BOX 6)

- *Engagement in multiple behaviours*. People tend to engage in several overlapping activities. In Campo Bello, a common scene was that women would tend the fire while at the same time breastfeeding their babies.
  Possible solution: the probably most straight forward solution would be to credit half of the total period to each activity. Another possible solution is to decide which activity to consider the dominant one and account for the primary activity only. The latter solution though involves a great deal of subjective judgement.

- *Distinction between economic food provision and food preparation.* This may especially be the case when activities are performed out of the usual surrounding (e.g. when a manioc tuber is peeled directly in the field where it is uprooted, does this count as food preparation time or as part of a woman's agricultural activities due to its *in situ* performance?) or when commodities are manufactured which are used for both, the household as well as the socio-economic system (e.g. the manufacture of a mortar and a pestle for husking rice, part of which gets sold at a later stage).
  Possible solution: Regardless of the spatial performance of tasks, any task related to food processing (i.e. a woman's peeling of tubers in the field) should be accounted for as belonging to the food preparation process. As to the manufacture of household items for direct food production (such as a mortar, for example), the time invested should be subsumed under the household system (despite eventual partial selling of rice). Only the manufacture of directly productive hunting or fishing equipment, as well as handicraft clearly destined for later selling, should hence be subsumed within the economic system.

BOX 6

"[In Campo Bello] visiting others after dark meant not only engaging in perilous travel through the forest, but was simply seen as intrusive behaviour. Life though, does not stop when the sun goes down and the hours of darkness not directly observed could not be simply equated with 'sleeping'. Luckily though, two neighbouring households were situated close-by, whom I was able to observe from my dwelling. On many nights, therefore, I would simply sit out in the dark and lean against the wooden beams of my home, where I had found a perfect place to unwind from the day's events. These night by night observations provided some estimates on how the hours of darkness are generally spent. Rather than simply coding the nocturnal cycle as 'sleeping', time for hygiene, eating, resting and sleeping was allocated for men, whereas the women's activity profile comprised also childcare in addition to these activities[4]" (Ringhofer, 2010)

4.5 Functional territory (stocks by land use categories)

In this section we will explain how to account for the different functional land use categories within the territorial boundaries of your system under investigation. The territory most likely entails different land use categories, meaning that each category is subject to different economic uses for different purposes. In most cases though, a significant share will be devoted to the extraction of biomass: land is used to grow crops, graze animals and extract wood and other types of food and raw materials. Another, albeit usually much smaller, fraction of the land will be covered by settlement areas, buildings, roads and foot paths as well as other infrastructures, while parts of the land area may even be (largely) untouched (e.g. nature protection zones, sacred areas, etc.).

Often though, a simple allocation of a plot of land to one of these land use types (biomass extraction, grazing, etc.) may not be that straight-forward as changes in land use over time may occur. Also, you may find that land is subject to multifunctional use due to rotational cycles that change their use during the course of one or several years. This is the

[4] For men, the following estimates per night (8 p.m. to 6.a.m.) were applied: 30 min for hygiene, 60 min for idleness, 30 min for eating and 480 min for sleeping. For women, the following estimates per night (8 p.m. to 6 p.m.) were applied: 15 min for hygiene, 120 min for child care, 15 min for eating and 450 min for sleeping.

case with fallows. In short fallow systems, land is left fallow for a period of up to one year, while in long fallow systems, cropland is not ploughed for several years. During a fallow period cropland may be used for animal grazing, wood and/or other biomass extraction, or simply remains untouched. Multifunctional types of land use comprise, for instance, agro-forestry, cropland used for animal grazing after harvest, or woodland used either for animal grazing or the extraction of feed and bedding material. Operationally, the rule of thumb is as follows: assign a plot of land to the land use type which matches the use of this plot in the year you are collecting the data. There are, however, exceptions. Some land use types, including for example long term rotation cycles, should be classified according to a more long-term perspective. Clear-cut forest land, for instance, that is bound to be reforested, should be allocated to woodland for wood production; also, land in short rotation, but not cropped in the specific year you are there, should still be accounted for as cropland.

Our functional territory/land classification entails various *land cover classes*, which are primarily differentiated according to the prevailing vegetation type. Within these land cover classes, different types of land use can be distinguished. These classifications correspond to the ones listed in the attached template.

(1) Woodland

The term ‘woodland’ is defined in a broader sense, as it also combines all types of scrublands, mixed grassland/woodland as well as land in early stages of succession after being clear-cut and left for reforestation. More specifically, we distinguish between four types of woodland:

- *Woodland for wood production:* land that is predominantly used for the extraction of wood (firewood or timber) including clear-cut land that is bound to be reforested or left for natural succession, fall within this section.
- *Grazed woodland/shrub land:* this land use class refers to all types of frequently grazed woodland or shrub land.
- *Succession woodland in shifting cultivation:* woodland from shifting cultivation with fallow periods longer than one year (all land not sown and cropped in this specific year) should be accounted for in this category. In some cases, this may also include land not yet covered by trees or shrubs. Make an annotation in the attached template if this land is grazed or used for wood extraction.
- *Woodland not used for grazing or wood extraction:* woodland not used for wood extraction or animal grazing belongs to this section. Woodland only used for hunting and gathering should also be reported here; in this case you should also take note of the hunting/gathering intensity.

(2) Grassland

- *Meadows:* all mown grassland used for the production of freshly cut grass or hay falls within this category. This includes also areas used for animal grazing after the cutting of grass. In this case, you should take note of the duration/intensity of grazing.
- *Cultivated pastures:* in this category you should include only grazing land if it is subject to cultivation practices like irrigation, drainage or fertilisation.
- *Rough grazing:* here you should account for all land with predominantly grass-type vegetation that is used for grazing animals but *not* subject to cultivation practices. Beware that it may be difficult in some cases to differentiate between rough razing and grazed woodland/shrub land – in this case an annotation should be made.

(3) Cropland

Cropland equally refers to the area actually planted with crops in the year of consideration, as well as short fallow cropland. Short fallow, in this context, refers to cropland that is fallowed for one year only or less. All other types of fallow (i.e. long fallow areas left for regeneration in shifting cultivation systems) are subsumed under woodland. You should indicate if land is harvested more than once a year and provide information on cropping intensities (share of cropland harvested more than once; number of harvests per year).

- *Cereals to fibres:* allocate according to the predominant crop type and make annotations on the major cultivars used (e.g. types of cereal sown). In case of a mixed cropping system, make an allocation according to the dominant crop and take a note of the mix of cultivars used.
- *Other crops:* here you should specify which other crops are cultivated.
- *Fallow:* this category includes both fallow lands as part of the crop rotation cycle and idle cropland which remains fallow for purposes other than crop rotation. Take a note of the length of fallow and the major crops grown.

On a general footnote, it should be borne in mind that allocating cropland to different cultivars needs to be consistent with the allocation of harvested crops to biomass categories in section 4.8.1.1. For example, harvests from land allocated to cereals should also be allocated to cereals. In the case of mixed cropping, when a consistent allocation of land and crops is not feasible, the land can be split according to the harvested amounts of crop.

(4) Permanent cultures

All land largely used for growing permanent crops, fruit trees or other plantations falls within this category. This covers a wide variety of cultures including vineyards, palm trees, orchards, tea, coffee or banana plantations. Please specify the type(s) of permanent cultures in the annotations.

(5) Built up land

This includes all land occupied by buildings of any kind (homes, farm buildings, communal and commercial buildings), paths, roads and any other built infrastructure. In addition, all land associated with buildings or infrastructure, such as yards and shoulders, and vegetation-covered recreational gardens or embankments (if *not* used for biomass extraction) should be subsumed under this land use category. Kitchen gardens used to grow spices or vegetables, on the other hand, should not be accounted for under this section but belong to 'cropland', grazed areas to 'grassland' and orchards to 'permanent cultures'.

(6) Water bodies

This is a rather heterogeneous land cover class as it comprises all types of rivers, ponds and lakes but also marshes, swamps, beaches or coastal land (e.g. mangroves). You should provide further information on the specific types of water bodies prevalent in your case study.

(7) Non productive land

Any kind of land not allocated to any of the above-mentioned categories is thus considered unproductive or unused land and should be accounted for in this category. There are two more issues to consider when you account for the different land use categories. First avoid *double counting of land areas*. The sum of all land use types should be coherent with the total area size of the functional (economic) territory. This means that every plot of land can merely be allocated to one of the above-mentioned land cover categories. Also, land harvested more than once a year (multi-cropping) should be accounted for only once (see cropland). This takes us to consider the second issue at hand: *multifunctional land use*. In case you are confronted with a multifunctional land use system (agro-forestry), you have to make a decision on the allocation to the individual land use categories. Your decision should be based on either the quantitative (mass of harvest or the economic value of different harvests) or the qualitative significance (local peoples' views) of the different types of use, or on both. In this case, you should provide detailed information on the characteristics of your land use system.

Accounting empirically for the different land use categories is again an endeavour that calls for a creative mix of methods. In a first step, you will probably have to gather a great deal of secondary information and documentation to obtain a first rough idea on the different land cover classes. You may be lucky to find statistical data from previous land use surveys, agricultural censuses, municipal development plans or cadastral records at the community or even individual plot level. Moreover, detailed regional land cover and land use maps, aerial or satellite images may also be a useful device for estimating the ratio of different land use categories.

In a second step, you will have to dare the descent into local empiricism at the community level. The range of Participatory Rural Appraisal (PRA)[5] methods may provide useful as you will obtain a substantial amount of information in a relatively short time. Community or resource mapping, for example, provide such method when you call for a village meeting and ask the participants to create a map, a representation of their territory, showing places that are important to them (the marketplace, sacred areas, the school, etc.) and including features of interest to you (e.g. location of agricultural and fallow plots). Once the individual plots and the kitchen garden area are located, you can proceed to manually measure their size using a measuring tape and eventually GPS (you will again be grateful for an assistant or two); the same goes for the housing area which in many cases includes not only the physical infrastructure (which was already measured for the stock account), but also the clearing around the house. We also advise you to make parallel cross-checks through qualitative household interviews or short surveys. Asking household heads on the species cultivated in kitchen gardens, the number and size of active fields, fallows and the cropping cycle will certainly provide useful complementary information.

4.6 Livestock (stock)

Quantitative information on domesticated animals is important for the quantification of stocks and for the calculation of feed demand and agricultural production. The template distinguishes between 12 types of animal species. What is requested here is information on the average number of *heads* for each of the main livestock species recorded during one year as well as their respective average *live-weight*.

Head: You should provide annual averages for the year under consideration, since within the timeframe of a year considerable fluctuations may occur. Please remember not to provide cumulative numbers, i.e. if a pig is fattened for six months and then replaced by another pig (turnover period 0.5 years), account for one pig only. But do provide a separate note on the turnover periods of certain animals. In some cases the average number of animals present during one year maybe difficult to estimate and only numbers of head present at the time of data collection is available. This should be mentioned in your annotations. However, our experience is that villagers usually know how many heads of cattle or pigs they own. In

[5] See, for example, Chambers, R. (1983) ‚Rural Development: Putting the Last First' or Narayanasami, N. (2009) 'Participatory Rural Appraisal: Principles, methods and application'

order to obtain an idea on the reproduction/vending cycles of domestic livestock, quarterly household surveys may serve useful.

Weight: The average weight of animals changes during the course of a year and may differ according to the individual species. What you should hence provide is a rough estimate only of the average weight of each species included in the stock account. Large animals like cows, cattle or horses usually range between 200 and 600 kg, grown up pigs between 70 and 200 kg, sheep and goats between 40 kg and 80 kg, poultry and cats around 1.5 kg, and dogs between 8 kg and 15 kg.

Livestock can be accounted for in two acceptable units: (a) *livestock weight*: the sum total weight of the livestock in a society, also calculated per capita by dividing the total mass by number of inhabitants. (b) *livestock unit*: The livestock unit, abbreviated as LU (or sometimes as LSU), is a reference unit which facilitates the aggregation of livestock from various species and age as per convention. In this text we refer to livestock units at 500 kg live weight. In other words, one livestock unit equals 500 kg.

4.7 Artefacts

Accounting for artefacts can be challenging (at times embarrassing), but exciting. It requires a great deal of ingenuity and creativity. Your research subjects may even find you peculiar that you want to weigh all the houses, infrastructure and belongings in the village. But if you don't take this personally, it might turn out in your favour. You might as well take the role of a clown and provide some humour and jest in the lives of the local people. They will come out and observe you, smile at what you are doing (with all seriousness of mind) and use you as a source of gossip in the village. This can be good and can help in deepening your rapport with the people, to take you more lightly than they did, to further remove the fears of a stranger in the village.

But before you actually set about weighing all that, there is some essential information you should have from simple observations in the village during the first couple of weeks. You should by now know how the different structures in the village look like and what are they used for. You should also know what artefacts the people own in their households that remain longer than a year (such as sewing machines, bicycles, boats, furniture, tools, etc.). Next, try to figure out a reasonable typology (or categories) of the houses, buildings, and infrastructure in the village. You should look for similarities between the architectural style and materials used in the constructions; usually certain types of buildings are used for specific purposes, but not necessarily. Your classification may look something like this: residential houses, kitchen huts, out-houses for storage, animal stalls or enclaves, pathways, school, dispensary, wells, etc.

To do this task effectively, it might be useful to have an assistant or two (under European or Western conditions, this may not be possible though) as well as a long measuring tape and a spring balance that can weigh heavy materials. What you need to do is to find out the weight per square metre (or foot) for each of the construction types, and then multiply this factor by the total area of that construction type in the village. As a first step, observe the different types of materials used in a representative construction type. Try to find lose samples of them in the village (wood pieces, bricks, wooden poles, grass, bamboo, etc.). Measure them and calculate their volume, then weigh them, and finally calculate how much a certain material type weighs per cubic metre. Once you have this, all you need is to calculate the total volume of each material used in your sample house, then multiply the total volume of each material type used with its factor weight. Your assistants will help you find the lose pieces in the village, or even dismantle a part of the house (if it is not dangerous or offensive to the owners), and in holding your spring balance while you record the weights and in stretching out the measuring tape to the other end.

Repeat this exercise with all the construction types in the village. Having done this, you now have a representative (factor) weight per square metre of each construction type in the village. Next, you have to measure the area of each of the construction types in the village to derive at a total area of each of these types. Finally, in order to derive the total weight of the built stocks in the village, you have to multiply the total area of each construction type with the factor weight (or per cubic metre), and sum the results of the weight of all the construction types. There you have it. It takes a few days to get this done though, and some amount of patience and ridicule (and mathematical intelligence to deal will squares and cubes!).

Besides buildings and infrastructure, stocks also include household artefacts that remain in the house for longer than a year. Make a list of them, and take a count of each with respect to every household. Next, try to estimate the weight of each of the artefacts. Some of them can be directly weighed by hooking them onto your scales, and for others a reasonable estimation must be made. It is assumed that after so much of weighing and measuring you would have gathered some idea on how much something could weigh by looking at it, or by trying to lift or push something. Once you have the estimated weights of each of the artefact types, simply multiply these by the number of each artefact in the village to arrive at a total sum.

4.8 Material and Energy Flows

4.8.1. Material flows

In MEFA it is a standard to present flow data as the sum of flows over a period of a full year (be it a calendar year or any other full period). This is why you have to consider seasonal fluctuations, especially when you collect your data just at a certain point in time (what is usually the case). The consumption of firewood for heating and cooking, for instance, may vary considerably between the summers and winter months. Hence, in order to calculate annual firewood consumption you need to obtain information on the specific seasonal consumption needs, either by interviewing or consulting secondary literature.

4.8.1.1. Biomass flows

In rural local systems biomass usually accounts for the most significant material. It is required for feeding the local human and livestock population and for cooking and heating dwellings. It is also used as building material and for generating income by selling biomass products on the market. Usually, rural local systems are characterised by a combination of subsistence and market economies; this means that a fraction of the primary or secondary production is for internal household use only, whereas the remainder is sold on the market. In some systems, certain crops are produced for the market only (cash crops), while others are grown for household consumption only. Whatever the case in your village, it is first important to get a qualitative understanding of the general patterns of local biomass flows. What are the main crops cultivated? How are they used? What are the estimated proportions entering the household, grown for the market, or used as livestock feed? What are crop residues used for? etc.

All these flows need to be accounted for separately, and we advise you to go about the MEFA logic as follows: first we look at the biomass *supply* (domestic extraction of biomass +

imported biomass – exported biomass), then at the biomass *use*. Biomass use splits the consumption of biomass into different domestic use types (food, feed, energetic use and other uses incl. losses). This means that we are interested in what and how much people eat, how much goes into livestock feeding, what is produced by domestic livestock and how much biomass is contributed for the generation of energy and income. Besides supply and use, there are two further distinctions: *primary* production and *secondary* production. Primary production includes all types of vegetable biomass and biomass from hunting and fishing (equal to domestic extraction - DE). In contrast, secondary production refers to all products from local livestock who are fed on primary production (or maybe also imported feed). In so doing, they convert primary production into secondary biomass products, such as eggs, milk or meat. While these products are not part of the DE account (as this would lead to double counting of animal feed and the mass weight of animal products), quantifying these flows provides us with insights into the contribution of the livestock system to local food and raw material production.

The biomass flow template is organised according to the *supply* and *use* distinction: there are three columns which record the domestic extraction and secondary production of biomass, imports from and exports to other socio-economic systems. This information is used to quantify domestic consumption (i.e. local supply). The consumption of biomass is then split in different domestic use types (food, feed, energetic use and other uses incl. losses). The template also contains the distinction between *primary* and *secondary* production.

(1) Biomass supply

Primary production

- *Primary crops:* ideally, primary crop harvests should be recorded at their ‘as is weight’ (incl. their moisture content) at the time of harvest and after threshing or husking (‘gross harvest’). Primary crop harvests also include the fraction used for seed in the next season.
- *Used crop residues:* primary crop harvests are often associated with large amounts of crop residues. These residues are not included in the weight calculation of primary crops and typically include stems (e.g. cereal straw), leaves or branches. One fraction of the available residues may be subject to further use by the local population or even exported. Most commonly, however, large parts of the crop residues are used for animal feed, as bedding material for livestock, as roofing material, fuel or any other kind of local relevance. Please note that in this category you should account only for the *used* fraction of all available crop residues. The remainder therefore - unused residues left on the field for compost, ploughed into the soil for fertilisation, burnt or discarded elsewhere - should not be included. You should also note that residues from the processing of primary crops are considered by-products and do not belong in this section either. Typical by-products include residues from milling (bran, oil cakes), sugar production (bagasse), pomace, or fruit and nut shells (coconut shells). You will find that in many cases primary crop by-products are subject to further use. Hence, their mass weight should be allocated to the specific use fraction the primary crop is put to (that is food, feed, energy or other uses).
- *Fodder crops:* this section entails all types of crops that are exclusively grown for livestock feed. It includes all types of roughage biomass produced on cropland, such as leguminous fodder crops, clover, grasses, fodder beets, or other green crops used as roughage (e.g. whole maize). Primary crops that are potentially edible for humans but used in the local system for livestock feed should not be included here (e.g. cereals),

but form part of the primary crop category. However, if this is the case, make a clear annotation in the template.

- *Grazed biomass:* this section includes all biomass grazed by domestic animals. Grazing may not be limited to pastures, but entails a variety of land use types (see land use section). If possible, the amount of grazed biomass should be assigned to the specific land use type where grazing takes place.
- *Wood:* this section includes all timber (for construction and manufacturing), fuel wood or wood for charcoal production. All types of branches, leaves, tree bark, or litter collected from woodlands should be accounted for under the category 'litter'.
- *Fishing, hunting, gathering:* the total mass of annual fishing, hunting and gathering yields should be subsumed here.

Secondary production

- *Milk:* includes all milk produced in the local system, regardless of further use or processing.
- *Meat:* the carcass weight of all slaughtered domesticated animals (including poultry) should be reported under meat. Carcass weight excludes all parts which are not primarily used as food (e.g. offal) but may include fractions which become waste at later stages of processing. By-products such as hides or horns should be accounted for under the category 'other'.
- *Eggs:* here you account for all eggs produced for human consumption or export.
- *Other:* all other animal products such as wool, hides or bones used for non food purposes should be subsumed here. Make sure you avoid double counting of products accounted for under the 'meat' category.

Biomass imports and exports

The import and export categories include all primary and/or secondary biomass products (raw or processed animal and plant-based products, live animals) which are brought in from other socio-economic systems (imports) or are transferred to other systems (exports). They may be purchased or sold, bartered or simply given away. Imported raw materials or semi-manufactured products can easily be allocated to the items listed in the biomass flow template in the appendix. Please note that imported and exported processed biomass products should be accounted for under the corresponding raw material section. Bread, for example, should be allocated to cereals, cheese to milk, jam to fruits and beer to cereals. While some processed items may easily be disaggregated, others may not. All these should be subsumed under 'processed foods'.

(2) Biomass use

The biomass supplied in the rural local system can be used for many purposes. The most essential use of this biomass is for human nutrition (food), but considerable fractions may also go into livestock feeding (feed) and/or the generation of energy (energy). All other usage (e.g. for manufacturing, construction, seed) as well as losses and wastes are subsumed under the fourth category 'other uses'. You will often find that biomass items can exclusively be allocated to one of the possible use categories: all fodder crops and grazed biomass, for example, are most likely used as feed, while all wood fuel may exclusively go into the provision of energy. Other biomass items may be used for more purposes. Take cereals, for example. They may primarily be used for human consumption, significant fractions, however, might go into animal feed or are used as seed. Crop residues, to take another example, may be used for livestock nutrition (feed), as bedding material (other uses) or simply as fuel (energy). In other cases, the use maybe split between a primary and a by-product. Oil crops may serve as an example for illustration: while the oil fraction may be used for human nutrition, the oil cake and other residues are likely used as feed or for energy generation. Before it gets too complicated though, here is our advice: remember the ABC method we described earlier and do not get entangled in too many (insignificant) details. Only if you feel the size of these flows is substantial for the functioning of the local system, then you should certainly consider the different use categories the item is put to.

The template distinguishes between four types of biomass use:

- *Food:* all biomass which is used for human consumption in the local system. It is the sum total of all food consumed in the individual households.
- *Feed:* all biomass (primary harvest, crop residues or by-products from processing) which is used to feed the local livestock population.
- *Energy:* all biomass which is used for the generation of energy (in most cases for combustion).
- *Other uses:* this includes (a) the use of biomass as a raw material for manufacturing and construction (timber, crop residues for roofing and bedding, fibres, containers, wool, hides and bones etc.); (b) the use as seed; and (c) all losses and unused wastes that occur during processing. Additional information on the nature of 'other uses' should always be provided in annotations.

The sum total of all four biomass use categories should equal the indicator domestic biomass consumption.

Practical considerations for data collection on biomass flows

Biomass flow data at such a disaggregated level is hardly ever readily available and you are most likely to generate it manually by weighing, interviewing, estimating, observing and other ingenious field methods. In a first attempt we advise you to get an estimate of the area under crop production by crop type in the village you are investigating. Sometimes you may find some of this information at the local agricultural or statistical office. If you are not lucky then there is no way round to physically measuring the fields. Using a pedometer can be extremely useful. Once you have gathered this data, you need to calculate the yields for each crop. Again, you may find the data readily available at one of the local offices. If not, estimate yields per unit land for each of the crops by observing actual harvests if possible, or by interviewing households. Household heads usually know how many tons of crops they sold in the previous year, or the income they generated from a given area of land. From the market price per ton, you may possibly estimate the mass. Get familiar with local units such as bags or bundles, and find out the actual weights of these. Try a variety of methods and estimates to cross-check your findings on yields.

Once you are familiar with the yields, you will need to estimate the ratio produced for the market and for household consumption. To arrive at household consumption, weighing food samples may be a useful method. Once you have established a good rapport with the villagers you may find a number of households let you take part in their private meal times for about three days, weigh their food (before cooking) and observe internal food distribution within the household. In doing so, make a list of food items consumed, including those purchased from the market. Do not forget to account for the firewood, kerosene or any other energy carrier that is used for the cooking[6]. At the end of this food sampling activity, you will know how much of each food type is consumed by individual household members, the fraction of primary and secondary products ingested, the amount of hunted, fished or gathered foods consumed, and the kind of imported foods consumed. Additional interviews should give insights into seasonal variations which need significant consideration within your accounts.

To estimate the amount of livestock biomass consumption, you need to become familiar with the diet composition of each farm animal, using a combination of direct observation, actual weighing of feed and interviews. Note what is imported and what is locally produced as fodder, or simply a by-product of some crops. Consumption by grazing can be estimated by counting the number of bites per hour. There exist a number of secondary sources on biomass consumption for cattle in most parts of the world, which may be used for reference and cross-checking. Once you have a notion of how much is consumed by each farm animal, you simply multiply the amount with the total number of livestock species in the whole village.

Secondary production from animals is again calculated using a combination of interviews, observation, weighing and measuring, where necessary. Here are some questions you may ask: how many eggs are laid by a chicken in a week? How can the fertility and slaughter cycle of the different farm animals be described? How many litres of milk are produced daily by the local cows? If you stay in the village for a few months, you will possibly get the chance to observe all of this yourself, and also be able to account for these flows manually. Of the total secondary production, you can estimate how much of each type is sold on the market if you subtract the household consumption of these products from estimates derived in the household food sampling method described above.

4.8.1.2. Non-biomass flows

The main material flows that occur at the local level are intricately linked to the system's dominant economic activity. As we are focusing on local rural systems, agriculture is likely to be the most important economic activity and biomass, in terms of quantity, the most important material flow. Having said this, however, you may also find significant amounts of minerals that are domestically extracted or imported and used. We have generally found the most important mineral flows to be related to construction (cement, sand and gravel), the provision of energy (fuel), and durable consumer goods (imported tools and machinery). But remember that it is your personal research question which determines which material flows you should focus on. Once arrived in your community, a first quick scan of individual households and the whole village provides you with some first ideas about the most relevant local non-biomass flows.

The main material categories of non-biomass flows are (1) metal ores and processed metals, (2) non-metallic minerals and processed products, (3) primary and processed fossil energy carriers, (4) other products of complex composition, and (5) imported or exported waste for final treatment and disposal. Each of these categories (if, of course, relevant in terms of mass) needs to be calculated along the following lines: the quantities domestically extracted, and the quantities imported and exported. The attached template provides a matrix for all the possible flows and stocks at the aggregate level you may come across in your system. You may of course introduce more detailed sub-categories, in case you need them.

As we are dealing with rural systems, however, the most significant material categories you will find in the field are probably non-metallic minerals (cement, sand and gravel, bricks and stones for the construction of buildings and infrastructure), fossil energy carriers (mainly fuel for transport, gas or coal for cooking and heating) and other products consisting of a range of different materials. These include all types of tools, vehicles and

[6] What you need for your analysis are some per capita figures on household energy consumption.

household appliances. In order to guide you the best way possible, we will discuss some of the empirical difficulties concerning the flows for artefacts, consumer goods and fossil energy carriers.

Flows for artefacts

Accounting for these flows can be quite demanding and requires some analytical efforts in problem solving. The most striking problem is the fact that many products are purchased rather infrequently with sometimes long intervals between two purchase moments. This has obviously got to do with the fact that many artefacts like durable goods or infrastructures may have a life span of various years. So, depending on your sampling period, you may record large flows (e.g. when a new house is built) or none at all. Both scenarios, however, are not representative for the general dynamics. To deal with this issue, we suggest two ways of approaching the estimation of annual flows for artefacts; both of which may be driven by different motivations (again, what is the research question) and actually lead to fairly different results:

(1) Actual flows

Here we are interested in the actual flows occurring during a specific year, irrespective of the fact whether it is a peak year or a year of low purchase. This requires the measurement or estimation of only those flows occurring in this particular year. If a house is built you have to estimate all materials extracted or imported for the construction of these flows and if one or more vehicles are bought you account for the mass of these vehicles as an import of metal in this particular year. For better illustration, let us look at the example of ‘constructing a stone building’ which may help explain better the two different ways of estimating flows:

- *Direct* estimation of flows:
  You can interview people directly on the flows. This means that you ask for imports and domestic extraction. In many remote rural systems you will only have limited alternatives on how minerals are imported. One option is to look at the travel frequency of a truck with a certain cargo capacity. From this you are able to calculate the (more or less) exact stone, brick or cement supplies needed for the construction of the house. Additionally you may cross-check your data with interviewing a key person at the stone pit on the amount extracted. Sometimes, the extraction of construction minerals may not be formally organised but informally within the household. Hence, get a clear picture on the situation first and find some knowledgeable people to ease your concerns!

- *Indirect* flow estimation via stocks:
  The other method is the investigation of the building itself, followed by a subsequent calculation of flows. You can measure the square meters and thickness of the walls and find out about its material composition (bricks with plaster made of 75 percent sand, 25 percent cement). Then you calculate the total volume for each material and multiply it with the density. As soon as you arrive at the weight of the house you can proceed to interview the people on the origin of the materials used; which were imported and which were extracted locally.

We advise you to use both approaches for the purpose of cross-checking (if appropriate).

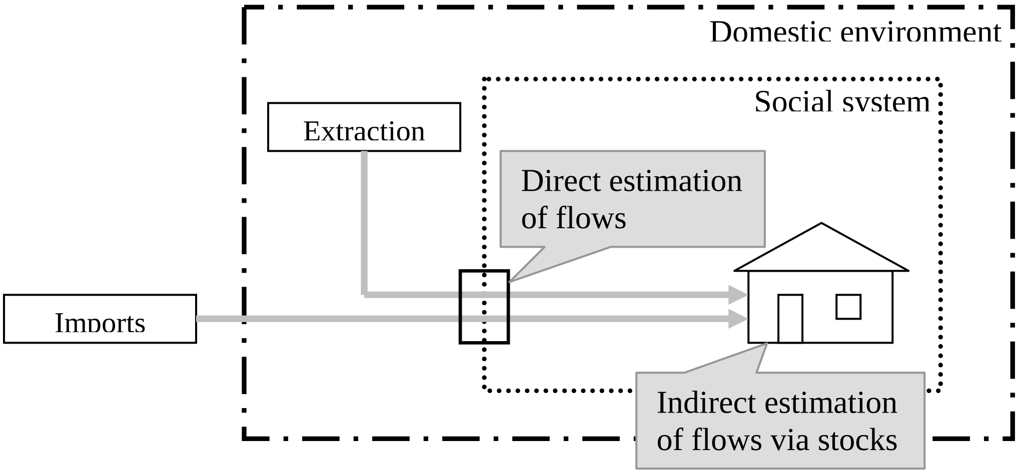

Figure 4.1. Schematic demonstration of the two ways for estimating flows

(2) Discounting approach

Here we are interested in the long term averages of these flows. This requires a discounting approach where you estimate the weight of the stock (see indirect flow estimation via stocks) and the average lifespan. Combining this information (dividing mass by lifetime in years) yields an average annual flow. A simple example may serve as a useful reference: take a simple stone house with 5 by 6 meters floor space outside dimensions. The walls are 50 centimetres thick and on average 2 meters high. The doors and windows you have to deduct. The floor is just a tamped bottom. The roof is a pitched roof with wooden beams and roof tiles. The stones account for approximately 47 tonnes, the tiles for 1.7 tonnes, and the wooden roof structure for 1.3 tonnes. Altogether this simple house weighs 50 tonnes. Suppose that the house has an average life span of 40 years. The average annual flow can therefore be calculated at 1.25 tonnes[7].

The house example shows that a dwelling contains both non-metallic minerals (stones and tiles) as well as biomass (wooden frame). In the template, wood needs to be accounted for under biomass. However, the method described here is appropriate to estimate the quantities via an estimation of stocks. This can be cross-checked with your estimation of the annual harvest from forest, in case the wood is extracted locally (see chapter 4.8.1.1 on biomass flows).

Keep in mind though that buildings and infrastructures may vary considerably between different cultures and tailor-made solutions may be required for specific problems. Houses in Europe, for example, are likely built of stone with an age of a few hundred years. In the case of Theyern approximately 10 percent of the buildings were built between 1700 and 1900, 25 percent between 1901 and 1960 and 65 percent of the buildings were built after 1961. It is therefore quite challenging to estimate the average lifespan for buildings, as it seems to be more a consequence of changing needs than a mere physical wear-out. Contrary to this we find different housing structures in rural areas of Asia or Africa, where dwellings are primarily wooden structures with grass or palm-thatched roofs. As they comprise organic

[7] Please note that this discounting approach can be used for *all* artefacts since we have defined artefacts as items that have a life span that is greater than one year.

matter only, they need to be renewed more frequently. Hence, finding out the average lifespan of these houses may probably constitute less of a problem.

So far we have provided you with some orientation on how to deal with flows related to the construction of houses and infrastructures. But the flows related to maintenance are just as important. Since these flows happen quite infrequently, what you need is to get an overview. Let us think of the roofing of a house that needs repair. You would have to look at the different roofing types and find out when the roofing material was last replaced or how many square meters of the roof had to be repaired at what intervals. Estimate these flows and decide if you want to record actual flows or discounted flows.

Consumer goods

Contrary to durable artefacts, consumer goods are purchased frequently during the course of a year. Since they tend to last for less than a year, no discounting approach is necessary. Non-biomass consumer goods entail a wide range of products and some of them may be of marginal relevance only. Again, stick to your research interest! Sometimes you may want to understand certain changes over time, especially if you are interested in documenting the transition process from locally produced biomass-based products to processed mineral-based products. Examples for consumer goods in rural contexts are salt, fertiliser, consumer batteries or wrapping for food and beverages. The easiest way is to look at the supply structure. You may be lucky to find just one shop where you could interview the owner or observe the buying frequency for a couple of days. Or, there may only be a few transport vehicles which import such products. You will generally find it quite easy to get estimates on what the whole community buys during the course of the week or month. From there, it is just a matter of multiplying the number in order to obtain the flow account for the whole year.

Another, yet more time-consuming (and at times culturally inappropriate) method includes the production of consumer diaries by the members of a household (see table 4.1.). Consumer diaries are tables that help people record the purchase of the most relevant products during a given period. Since income levels and household size are usually influential factors for the per capita consumption, we advise you to create homogenous households clusters and depending on the needed accuracy involve a 10-30% sample of households. Once done the sample, you will have to find out about the composition and weight of these goods in order to estimate the flows for that period. With this information and some knowledge on the annual variations you will arrive at the annual flows.

Week:		Name:		Household:			
Products	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Salt (1 kg)	1						
Fertilser (50 kg)					7		
Soft drinks (1 litre glass bottle)		8			6		
……							

Table 4.1. Example of a simple consumer diary

This method was originally developed for consumer expenditure surveys at the national level, but now also serves as an aid for calculating the purchase of non-biomass flows. You may even generate data on biomass consumption that way (food, beverages, furniture, etc.) by just additionally tracking if the product has been imported or extracted. These figures can then be cross-checked with the data generated from agricultural production. Of course, instead of setting up your own consumer survey you may also base your estimates on national consumer data, if available and feasible.

Fossil energy carriers

Fossil energy carriers include a range of products from diesel, petrol, kerosene, coal and gas. These are used for transport, agricultural equipment and other machinery, lighting, cooking and heating. Data on fossil energy carriers are meaningful for understanding the degree of dependency on imports, for getting the ratio between renewable and non-renewable energy sources, and for understanding at which point of the continuum the local system is positioned in its transition process from one regime to another. Accounting for fossil energy carriers has a nice attribute too: it is a fairly easy undertaking and the data you obtain are usually of high quality. Here we will present just a few of the several approaches for generating this data:

First get an overview on what types of fossil energy carriers are used for which purpose. Get an idea of the purchasing channels: find out, for instance, if single households organise their purchase from outside or if there is a local supplier (petrol station, general dealer, etc). Sometimes you may find it easier to get information on import flows rather than on consumption. In most cases you will have to find out consumption patterns, which almost always equal import flows (be aware if a local dealer provides fossil energy carriers to outside residents of your local system; if this is the case, you will have to record the relevant share as import/export).

The most straightforward way to survey fuel consumption is to interview car or truck owners on their annual fuel consumption. In some cases people import several barrels a year; so they probably know. However, you may also be less lucky. A quite common method therefore to generate data on fuel consumption of vehicles is to take stock of the fleet (brand, model, power, diesel/petrol version, year of manufacture, average consumption per km) and ask for the annual mileage. You should be able to get this information with a few interviews only. You can quite easily check consumption per km by asking the manufacturer. And finally, do not forget to convert your litres (volume) to kilograms or tonnes (mass).

For agricultural equipment like tractors, tillers or also boats you may choose the same approach. In many cases, however, you will have to ask for the operating hours instead of the mileage. Kerosene for lighting and cooking is often best to be recorded via the number of jerry cans (mainly 5 or 20 litres) purchased throughout the year. In case of use of liquefied propane gas (LPGs) the number of refills or number of purchased containers in combination with the loading capacity (best in kg) allows you to calculate the annual consumption. If fossil fuels are used for heating, most people have a good knowledge of their annual household consumption due to specific storage capacities and just very few refills throughout the year. Coal might be known by the number of bags purchased per year. Just check what kind of coal it is since there are big differences in factor weight and upper heating value.

Note: Since you might have to make estimations on stocks anyway (see chapter on artefacts) it would be quite efficient to gather additional information on the energy consumption as described above. By doing so, most of the information needed for the calculation of the fossil energy carriers will then be readily available.

4.8.2 Energy flows (incl. electricity)

Both, the material and energy dimensions of social metabolism usually have large overlaps; due to the application of different measuring units (mass vs. energy content), however, they both provide different insights. In socio-ecological studies concerned with the social metabolism of local systems, we have a broader perspective on energy than e.g. in conventional energy balances. While conventional energy balances often consider commercial forms of energy only, the way we generate energy flows, such as food for humans and feed for draft animals and firewood, provides us with important data on what are often considered the most important energy flows in local rural systems (see Haberl 2001 on the basic concept of energy flow accounting).

In our energy accounts we consider all energy-rich materials (all materials which can be burned, that is, which have a heating value) as primary energy, regardless of how these materials are used. This means that all domestic extraction, imports and exports of biomass and fossil energy carriers are accounted for as energy flows. In addition to these flows which have both a mass and an energy component and thus are also included in the material flow account, imported or exported electricity and locally used wind and hydropower also need consideration as energy flows. With the exception of these flows we can use the data collected for the material flow account to calculate energy flow data. This is done by applying material-specific and appropriate (with respect to moisture content) gross calorific values (upper heating values) to convert mass flows into energy flows. This is done automatically in the energy flow template. In case of electricity imports (which are not included in material flow account), a simple and feasible way is to ask households about their annual electricity bills. Since it is easy to get price information from one household or the electricity supplier you can easily calculate the kWh from the annual cash spent on electricity (just use conversion factors to get kilo joules). Sometimes you can get overall information on the electricity consumption directly from the power supplier.

5. Functional interrelations and headline indicators

5.1 Basic system description and system interrelations

Before we speak of indicators, it might be useful to remind ourselves once again of the objectives of such a local study. As spelled out in the introduction, an important goal of this manual is to help scholars obtain insights into the biophysical variables of a local rural system, their interrelations and dynamics for a sustainability analysis. In other words, the aim is to know how societies organise material and energy flows with nature and other societies for their sustenance and reproduction, how they colonize land through the use of labour and technology, and the consequences this has for sustainability (environmental and, to some extent, also social). These insights are not only of interest for scholars, but may also prove useful for development practitioners in order to design appropriate interventions into a social system.

To this end, we might first want to remind ourselves what a 'system' is and what their emergent properties are in the context of sustainability into which we want to intervene. In section 3.2 we defined a social system as a hybrid between the cultural and material realm, whose existence depends on its ability to constantly reproduce itself and its boundaries. In this sense, a social system is in fact a 'socioecological' system that consists of "a group of interacting components, operating together for a common purpose, capable of reacting as a whole to external stimuli" (Spedding 1996). So to say, a systems approach recognises the inter-linkages of the system's components and processes that affect each other.

Let us take the example of a tree as a system whereby its components such as roots, leaves and branches interact with each other for the common goal of sustaining and reproducing the tree. The root, for example, would not exist on its own were it not for the others. However, damage to the root will affect the other parts and inevitably the entire tree. Thus, it is not sensible to look at one component by itself without recognising that what it does and what happens to it will affect the other parts of the system or the whole. Having said this, it would equally not be meaningful to classify the physical parts of a system as 'sub-systems' since rarely any of these provide an independent function that could exist on their own. Rather, relevant system functions cut across more than one physical component. This is why a more meaningful way of classifying sub-systems might be based on their functional differentiations. Thus, in the context of a tree, to look at the 'water-transportation system' or the 'energy system' as functional subsystems would be more appropriate.

Similarly for social systems, we prefer a functional differentiation and classify the systems as follows: resource use system, energy system, food system and time-use system. While all of these relate to each other and offer an important function to the survival of the whole social system, they can also be studied in their own right. An additional advantage of such a functional classification is its direct usefulness for development practitioners. Rather than focussing on individual (at times seemingly disperse) parts of the metabolic profile of a society (though interesting for academia), our functional classification facilitates a more practical understanding of the interrelation of system dynamics.

Higher level interventions - often in the form of regional development programmes - aimed at improving and expanding the local infrastructure (such as roads, bridges, dams) are prone to increase the annual throughput of resources even after the intervention ends, as materials are needed for maintaining these infrastructures. At the same time, all kinds of interventions, though to varying degrees, have an impact on the functional systems of the community. For example, introducing transportation infrastructure into a village may bring the market closer to the local people. This might fuel the production of cash crops for which in turn more imports (e.g. fertiliser, machinery, etc.) are needed. Also, a growing dependence on exports is likely to intensify the food production system which in turn will affect land use and increase the need for more labour. With growing population trends more resources will be required from the same territory; encroachment into new areas and eventual emigration will be the consequence.

From the above description it might appear that socioecological systems are stable, static and predictably following simple cause-effect patterns. One has to bear in mind that here we are only focussing on the biophysical variables and their dynamics for a sustainability analysis in ecological terms. However, in reality a socioecological system is rather complex since, besides material and energy flows, it also includes information flows processed by human "agents"[8] and their institutions such as norms, practices and rules. Similar to biophysical components, institutions create and maintain themselves dynamically through processes of communication. Communications are not subject to the thermodynamic principle of conservation; they create and maintain shared meaning, understanding and expectations, including the societies' own physical survival and well-being by a defined and organised flow of matter and energy. Thus, in reality, socioecological systems are complex - manifested in a combination and interaction of all these flows - biophysical and non-biophysical - across temporal and spatial scales. In other words, the complexity and emergent properties of socioecological system derives itself from the dynamic "set of *interacting cybernetic relationships* and described in terms of *stocks and flows*, linked by (positive and negative) *feedback loops* with *different rates* and *different time delays* between them" (van der Leeuw & Aschan-Leygonie 2005).

However, this manual is not intended to support researchers capture all the dynamics and emergent properties of complex socioecological systems. Our goal in this manual is to be able to define a characteristic *metabolic profile* (see section 2.1) of a given social system in terms of its stocks, material and energy use, and in the way they allocate their labour time (across age and gender) to relevant subsistence and reproductive activities. Below we describe briefly some of the relevant functional sub-systems mentioned previously along with suggestions on a few useful indicators and the interpretative power they hold for sustainability studies. The lists of indicators we present below are rather extended and they do provide interesting insights on the systems biophysical organisation. However, some of them are highly relevant when it comes to describe a society's *metabolic profile*, such as population density, livestock density, Domestic Material Consumption (DMC), Domestic Energy Consumption (DEC), share of biomass in the total energy use and time in agriculture and food production.

5.2 Societies' stocks (including infrastructure)

We begin with a description of societies' stocks that require to be reproduced by the different functional systems. In section 3, we have discussed that the four main categories of a society's stocks are human population, livestock, territory and man-made artefacts. Every society consists of a certain human and livestock population and is entitled to exploit a spatially explicit territory, either through customary rights or legal entitlement. At the same time, humans also accumulate artefacts and construct infrastructures such as individual dwellings, buildings, streets, machines, boats, tools, wells, etc. All of these need to be

[8] "Agents" reach far beyond "human actors". Agents may be defined as an entity complex enough to have self-governing features that is not only an internal driver - action loop but also a reflexive loop taking into account other actors and being able to learn.

maintained at times and reproduced with the continuous investment of materials, energy and human labour. The larger the stocks account of a social system, the higher the material, energy and labour requirements. In this sense, the amount of a society's stock account is also indicative of the metabolic rate the system must organise for regular maintenance and reproduction activities (see sections on resource and energy use below).

Here are some indicators for accounting for society's stocks, both in its size and flows:

- *Human Population* is the total number of humans in the rural system, and disaggregated by gender and age categories.

- *Share of agricultural population* (in percentage) is useful to understand the level of dependency on land and agriculture as a source of income in relation to the non-agricultural population.

- *Population growth rate* (in percentage) is the annual increase in population based on the number of births, deaths, in- and out-migration. Additional information such as infant mortality and total fertility rate are useful.

- *Territory* (in hectares) is the total area a society is entitled to exploit either by customary rights or legal entitlement. It is useful to provide disaggregate figures on the territory according to land cover and land use.

- *Share of cropland from total area* (in percentage) is an indicator to understand the land use pattern and preference, and helps to calculate productivity.

- *Population density* (number/km^2) per unit of area measures the pressure on land, and thus on resources.

- *Livestock* (tons per capita) is calculated from the total weight of livestock owned by the society and divided by the total human population.

- *Livestock unit* (number per unit area) is an indicator for available land for fodder production per unit of livestock, and informs us of the scope to meet the fodder demand.

- *Artefacts* (tons per capita) is the weight of all artefacts, including individual dwellings, streets, buildings, machines, etc. and divided by the total human population.

- *Built up land* (hectares per capita) is the area of land used up by construction (housing and infrastructure) and divided by the total human population. It is an indicator for development in terms of infrastructure.

5.3 The Material Use System

As mentioned previously, any social system relies on its environment for a continuous inflow of materials for its maintenance and reproduction and for the absorption of outflows such as wastes and emissions. The extracted materials provide societies with the necessary nutrition, heating, cooking, and infrastructure. By and large, no rural society can subsist entirely on the material inflows extracted domestically; they depend on imports, and thus on trade. Usually, rural systems are a hybrid of subsistence and market economies, exporting agricultural surplus or cash crops, and importing commodities not available or produced locally.

We characterise the resource use system of a society by its metabolic profile. The metabolic profile comprises of a number of key indicators which describe the quantity and quality of annual resource flows. The corresponding metabolic rates refer to the quantity of resource throughput per capita per year. By and large, rural systems live predominantly of agricultural production; hence the share of biomass as a percentage of total resource consumption is usually high as compared to other materials, and an indication of the level of direct reliance on land and water bodies. The share of imports in the total domestic resource consumption conveys the level of dependency on the outside world, and may also be indicative of food security. Higher level interventions, development programmes, welfare services and subsidies can alter the composition of materials and their ratios in any given system with implications on medium and long-term sustainability.

Here are some useful indicators for understanding the resource use system and their dynamics, all accounted for in **tons per year**:

- *Domestic Extraction* (DE) (per capita) of various material types (minerals, biomass including fish and hunted animals) is an indicator of the level of activity in the primary sector for subsistence and for the market.

- *Domestic Extraction* (DE) (per unit area) is a productivity indicator for various categories of biomass (agricultural crops, fodder, fish, etc.).

- *Imports* (per capita) is the total quantity of incoming materials the society organises via trade to meet its metabolic requirements.

- *Direct Material Input* (DMI) (per capita) is the sum of total imports and DE and indicative of the total volume of resource throughput the social system requires in order to maintain its metabolism.

- *Import dependency* (in percentage) is the share of imports per DMI and conveys the level of outside dependency on trade for necessities.

- *Exports* (per capita) is the total quantity of materials (agricultural crops, dairy products, livestock, handicraft, etc.) a society trades on the market as part of its metabolic arrangements with other societies.

- *Domestic Material Consumption* (DMC) (per capita) is the material metabolic rate for the actual consumption of materials in a society. It is calculated by subtracting exports from DMI.

- *Share of biomass* (in percentage) in DMC as compared to other materials used by the social system. It informs us of the system’s level of reliance on land and renewables.

- *Share of industrial products* (in percentage) in DMC informs us of the system’s reliance on manufactured commodities that must be obtained through imports.

- *Material burden on the environment* (DMC per unit area) is an indicator of the environmental pressure a system creates due to its metabolism. Any kind of resource throughput must either be extracted from the domestic environment, or is discarded as waste onto the domestic environment, causing pressure on the available land.

5.4 The Energy System

Energy constitutes the basis for all life on earth, and the one single source is the sun. Through the process of photosynthesis, solar energy is transformed into plant biomass which then is consumed by animals across trophic levels in a complex web of life. The amount of energy stored in plants is called ‘net primary production’ and is appropriated by all life forms for their existence. Conversion of solar energy into plant biomass not only takes place on land, but also in the oceans and other water bodies which gives way to marine life.

For most of the period of human existence, biomass was the single most important source of energy, be it in the form of nutrition, or wood for cooking and heating. This way of energy utilisation was the central feature of hunters and gatherers as well as pre-industrial agrarian societies (see Sieferle 2001, Krausmann et. al.2008). While hunters and gatherers drew their energy directly from the natural ecosystem around them, the agrarian sociometabolic regime actively managed terrestrial ecosystems to increase the output of useful biomass and energy, drawing on animal power for transportation, tilling, or water harvesting; but that too in essence was dependent on animal fodder and feed. In this sense, land and human labour was a limiting factor since it determined the quantity for the production of biomass. Thus, human activity was based on renewable sources of energy and had its limits when it came to extensive and intensive use of the environment. On the other hand, it was a necessity to maintain land fertility so that the flow of plant biomass (energy) for the needs of humans and livestock would continue. From the eighteenth century onwards, humans discovered fossil energy (coal and petroleum), a formation of plant biomass trapped under the earth for millennia that provided an additional source of energy to humans, a source that was not area-dependent. Thus land and labour was no longer a limiting factor for accelerating human activities to draw more and more resources and services from nature. The biosphere did no longer constrain energy availability, but fuels could be drawn from earth’s submerged biotic history. This allowed the development of advanced technical devices to replace human labour and set most people free from food production.

Thus, an understanding of the energy system in rural local systems is highly relevant. Some interesting questions in this context would be: how is the energy system organised? To what extent does the local system depend on biomass and land for their energy supply? Where do the other sources of energy come from (for lighting, mobility, running of machines)? How vulnerable is the system to future energy supply shortages?

Here are some useful flow indicators for this domain, in **Gigajoules (GJ) per year**:

- *Direct Energy Input* (DEI) (per capita) is the sum of energy imported and domestically extracted and is indicative of the total volume of energy throughput the social system requires in maintaining its energy metabolism.
- *Imports* (per capita) is the total quantity of energy imported via energy carriers such as fossil fuels, electricity, kerosene, etc. (subsidised or not).
- *Import dependency* (in percentage) is the total share of imports per DEI and conveys the level of outside dependency for its energy metabolism.
- *Electricity consumption* (per capita) is indicative of the level of modernisation and the dependency on electrical appliances and lighting.

- *Exports* (per capita) is the total quantity of energy contained in certain materials (agricultural crops, dairy products, livestock, etc.) the society must sell on the market as part of its metabolic arrangements with other societies.

- *Domestic Energy Consumption* (DEC) (per capita) represents the energy metabolic rate for the actual consumption of energy in a society. It is calculated by subtracting exports from DEI.

- *Share of fossil fuels* (in percentage) of total DEC as compared to biomass or animal power used by the social system. It is indicative of the systems' dependency on non-renewables.

- *Share of renewables* (in percentage) of total DEC conveys the dependency on biomass for its energy source.

- Technical Energy Supply (Total Primary Energy Supply) (per capita) comprises all technical or commercial energy carriers (coal, oil, gas, fuelwood, electricity).

- *Energy density* (DEC per unit area) is an indicator of the environmental pressure a system creates due to its metabolism. It is calculated by dividing the total DEC with the land area available to the system.

5.5 The Food System

Analysing the strategies of food provision is central to the study of rural local systems. For a better grasp of the entire functional system, we suggest to differentiate between two functions: 'food production', on the one hand, and 'food consumption', on the other hand. Food production and food consumption may refer to different system boundaries. For food production, the relevant system boundary is the territory and eventual water bodies from which food may be drawn. All food produced or directly consumed by animal livestock within these system boundaries is counted as part of food production – even if it is finally exported. It is important to avoid double-counting: only the plant biomass extracted by livestock or humans should be counted, plus the harvest of wild animal biomass. Animal biomass from livestock is not to be counted as a primary resource, but as a transfer flow within the system. As for food production, some of the facts we are interested in are: what is the fossil fuel input in the production of the key staple food? How much labour is invested per unit area? What is the relative size of the crop system versus the livestock system? What is the relation between food hunted/gathered versus produced by agro-and-horticulture (in weight, calorific or protein terms, in time investment?

Here are some useful indicators on food production that are accounted for **per year**:

- *Food production* constitutes the entire production of edible plant and animal-based biomass and is calculated in GJ.

- *Share of animal products in total food production* informs us of the significance of the livestock system in food production. It is accounted for in GJ.

- *Cropland per capita* (hectares per capita): two variables are of interest here; the amount of cropped area per year (net area) , on the one hand, and the cropped area incl. fallow land, one the other hand (gross area).

- *Cereal yield* (per hectare) refers to the production of cereals (wheat, barley, etc.) per unit of sown area. .

- Animal conversion efficiency is the total output of animal products per total feed intake. It is accounted for in GJ per GJ.

- *Food production from hunting, gathering and fishing* refers to the calorific production of all productive/extractive activities practised in the local system. It is calculated by adding the nutritional energy from hunting, gathering and fishing to the food production energy. It is accounted for in GJ.

- *Food exports relative to food production, incl. hunting, gathering and fishing (in percentage)* is the share of nutritional energy exported from all the nutritional energy produced within the system. It is calculated by dividing exports by the total calorific production.

- *Land productivity* (GJ per hectare) is calculated by dividing the annual agricultural production by the entire agriculturally used land area..

- *Labour per area* (hours per hectare) is the amount of labour time invested in agricultural production divided by the agriculturally used land area.

- *Total food output per unit of agriculturally used area. It is accounted for in GJ per hectare.*

- *Labour productivity* (MJ per hour) is an efficiency indicator of agricultural labour input. It is calculated by dividing the entire food production by the amount of agricultural labour time.

- *Biomass extraction per capita of the agricultural*ly active population (in GJ per capita).

- *Food output per capita of the agriculturally active population* relates to the edible biomass ratio only.

Food consumption, on the other hand, refers to the demand side of food, whether it is produced locally or imported from elsewhere. The system boundary is determined by the human and livestock populations, respectively. Usually, human food consumption needs to be accounted for separately and will include also “intermediate” flows such as milk, cheese or meat from livestock.

Here are some useful indicators, which are always calculated in **capita/day**:

- *Food consumption* is the average amount of food consumed by the people in the local system.

- *Share of nutritional energy from agriculture* (in GJ) is the percentage of consumed nutritional energy derived from local agricultural food production (incl. permanent cropping, fallow cropping and kitchen gardens, if any). It is indicative of the system’s self-sufficiency and calculated by dividing the nutritional energy consumed from agriculture by the total nutritional energy consumed by the system.

- *Share of nutritional energy from hunting, fishing and gathering* (in GJ) is the percentage of consumed nutritional energy that comes from hunting, fishing and gathering activities. It is an indicator of the relative importance of non-agricultural food procurement and its calorific contribution.

- *Food imports* (in GJ) is the percentage of consumed imported nutritional energy and indicative of the system's market dependency/self-sufficiency for meeting internal nutritional demands. It is calculated by dividing the nutritional energy derived from imports by the total nutritional energy consumed by the population.

5.6 Time Use System

Adding the time component to the MEFA framework reveals in fact two interesting insights: first, in historic agrarian regimes we could see a direct link between the amount of (human and animal) labour invested and land colonization. Still today, there exist some local rural systems which apply human (and animal) labour only for agricultural production and thus interaction with their natural environment. Therefore, investigating into the use and intensity of agricultural labour gives us some idea on land pressure. A second and probably more straight-forward insight we get from the Time Use System are the 'social costs' a certain metabolic regime has to bear in terms of human labour and possibly uneven labour distribution (particularly in terms of child labour and women's labour burden). For all time use indicators, distributional features are as interesting as overall flows.

Here are some indicators for this domain, which are all calculated in **hours per capita and day**:

- *Time invested in the person system* across gender and age categories represents the sum total of the following activities: sleeping, eating, rest and idleness, leisure activities, and study and education.

- *Time invested in the household system* across gender and age categories represents the sum total of the following activities: care for dependents, food preparation, house building, repair & maintenance, and domestic chores.

- *Time invested in the community system* across gender and age categories represents the sum total of the following activities: public sports and games, visiting friends and relatives, ceremonies and festivals, and communal work and political participation.

- *Time invested in the economic system* across gender and age categories represents the sum total of the following activities: agriculture (or subsistence/cash crop agriculture), hunting, fishing, gathering, trading, wage work, kitchen garden, manufacture & handicraft, and animal husbandry. The sum total would be regarded as labour time.

Here are some more useful indicators for gaining a better understanding of the time invested into the food production system. They are all accounted for in **percentage**:

- *Share of labour time in agriculture* is the sum total of time invested in agriculture and animal husbandry.

- *Share of labour time in total domestic food production* is the sum total of time invested in agriculture, kitchen gardening, hunting, gathering, fishing, and animal husbandry.

- *Share of children's time in agriculture* accounts for the time invested in agriculture and animal husbandry by children between the ages 6 to 16.

6. Post Script

In the appendix below, you will find excel-templates that can guide data collection and its organisation into excel sheets. Later, we should soon be uploading programmed excel sheets that you can download and work into them directly, together with conversion factors and formulae. In the appendix, we also attach some filled in templates on material, energy, time and society's stocks for some of the cases we have worked with. This way, you can get an idea of the estimates of probable numbers, and a feeling for them. The appendix also contains selected abstracts of published papers in this direction, in case you wish to read some of the work already done in greater detail. However, a full paper on some of the cases we have compared rather recently can be downloaded as a **social ecology working paper number 121**, "*Sociometabolic regimes in indigenous communities and the crucial role of working time: A comparison of case studies*" (http://www.uni-klu.ac.at/socec/inhalt/1818.htm).

The local studies manual is a work in progress with several sections still to come in, such as expanding on complex adaptive systems, integrating monetary units with biophysical indicators and to suggest how one can meaningfully interpret these indicators for a sustainability analysis and development goals. There is also a plan to introduce methods for undertaking a stakeholder analysis to be able to evaluate the sustainability of the system in terms of social processes and dynamics. Thus, we are grateful for any feedback for improving this manual as it stands in terms of comprehension, and practical application. You can email your feedback to:

Simron Jit Singh: simron.singh@uni-klu.ac.at

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Appendix 1: Abstracts of selected publications

Sociometabolic regimes in indigenous communities and the crucial role of working time: A comparison of case studies

Marina Fischer-Kowalski, Simron J.Singh, Lisa Ringhofer, Clemens M. Grünbühel, Christian Lauk, Alexander Remesch (2010)

Published as Social Ecology Working Paper 121
http://www.uni-klu.ac.at/socec/inhalt/1818.htm

Abstract

In the context of the broad discussion of visions for a more sustainable future, we present findings from four case studies of indigenous communities in various world regions. Guided by Sieferle's theory of sociometabolic regime transitions, we compare their profiles in material and energy use, and their time use patterns. Each of these subsistence economy based communities bears some traits marked by interventions from higher scale levels (such as development programs, health services or transport infrastructure) connecting them in some way to industrial society. But apart from these features, the endogenous characteristics of the local communities correspond well to what should be expected according to the theory of sociometabolic regimes: low energy consumption based almost exclusively on biomass as well as low rates of material use, and working time patterns according to Sahlin's "original affluent societies" and Boserup's hypothesis of labour intensification. In conclusion, we suggest that traditional development and aid policies should be aware of the intricate link between demography, labour time, land degradation and subsistence when aiming for sustainable interventions and human well-being.

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Fishing, Foraging and Farming in the Bolivian Amazon: On a Local Society in Transition

Lisa Ringhofer (2010), Springer, Netherlands. (Book)

Abstract

Empirical in character, this book analyses in detail how the indigenous Tsimane' of Campo Bello, a remote village in the Bolivian Amazon, interact with their natural environment. Following a common methodological framework - the material and energy flow (MEFA) approach - it gives a detailed account of the local peoples' management of energy and material resources, land and time use and provides biophysical sustainability indicators. The local community described in this publication stands for the many thousands of rural systems in developing countries that, in light of an ever more globalising world, are currently steering a similar - but maybe differently-paced - development course. This book presents methodological and conceptual advances in the field of sustainability science and provides a vital reader for students and researchers of social ecology, ecological anthropology, and environmental sociology. Since the book also intends to improve our understanding of the possible sustainability impacts of local/regional development interventions, it equally contributes to improving practical development work methods.

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Milk, manure and muscle power. Livestock and the transformation of pre-industrial agriculture in Central Europe

Fridolin Krausmann (2004). Published in *Human Ecology* 32(6), 735-773

Abstract

The process of industrial modernization was characterized by fundamental changes in the interaction of socio-economic systems with their natural environment. This paper reflects on this transformation process from an ecologically informed perspective, focusing on the interrelation of local populations, their specific mode of production, and the (agro-)ecosystem. Four Austrian villages in different agro-ecological zones serve as case studies for a comparative analysis of different types of farming systems and changes in these systems over time from the early 19th century to present. The paper presents empirical results and aims at contributing to the discussion of relevant topics in human ecology and environmental history. Focusing on the changing significance of livestock in agricultural production systems, it addresses issues including: the relation of population density to intensity of land use; soil fertility and nutrient management; the sustainability of pre-industrial agriculture; and the gradual opening of locally closed cycles during industrialization and its effect on the landscape.

See also:
Krausmann, F., (2008). **Land use and socioeconomic metabolism in pre-industrial agricultural systems: Four nineteenth century Austrian villages in comparison.** IFF Social Ecology Working Paper No. 72. Available for download at http://www.uni-klu.ac.at/socec/inhalt/1818.htm

Cunfer, G. and Krausmann, F., (2009): **Sustaining soil fertility: Agricultural practice in the Old and New Worlds**, Global Environment 4, 9-43.

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Environmental Relations and Bio-physical Transition: The case of Trinket Island

Simron Jit Singh & Clemens M. Grünbühel (2003).
Published in *Geografiska Annaler,* 85B (4).

Abstract

To what extent is an island economy cut off from the rest of the world? Defined as a mass of land bounded off by water, island societies connect and exchange with their surroundings rather intensely. Based on empirical research, the paper explores the role of a 'remote' island society on Trinket in generating or sheltering itself from the process of globalisation in which contextually given borders are transgressed and displaced. To this end, we apply the concepts of *societal metabolism* and *colonising natural processes* operationalised by Material and Energy Flow Analysis (MEFA), and Human Appropriation of Net Primary Production (HANPP) respectively. Using these biophysical indicators, we describe the transition from a metabolism based upon the natural environment to metabolism based on exchange with other

societies. Data presented in this paper further reveals a process of industrialisation and integration into the global market of a so called ‘closed’ and ‘inaccessible’ island society.

***

Socioeconomic Metabolism and Colonization of Natural Processes in SangSaeng Village: Material and Energy Flows, Land Use, and Cultural Change in Northeast Thailand

Clemens M. Grünbühel, Helmut Haberl, Heinz Schandl, and VerenaWiniwarter (2003)
Published in *Human Ecology*, Vol. 31(1).

Conceptualizing environmental problems as sustainability problems contributing to local and global environmental change requires an understanding of how societies cope with their natural environment. Indicators for society–nature interactions are fairly well developed for national-level analyses. This study adapts some of these indicators to the local level and relates them to a qualitative assessment of economic and cultural change in a single community. Indicators are derived from material and energy flow accounting methods and address two major objectives: Firstly, to identify mutual influences between the global and the local level. Secondly, to assess future potentials of environmental pressures and impacts that can be expected to occur as such communities follow a path of further modernization. This study of a small rice-farming community in Northeast Thailand deals with physical as well as sociocultural aspects in order to produce a broad picture of society–nature relations. The indicators developed portray a society in the midst of transition and rapid modernization. This becomes apparent when comparing the results to those of similar studies in traditional and industrial societies. What we see is a community struggling to adapt to global influences, while at the same time maintaining subsistence with traditional coping mechanisms.

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Social metabolism and labour in a local context: Changing environmental relations on Trinket Island

Simron Jit Singh, Clemens M. Grünbühel, Heinz Schandl, and Niels Schulz (2001). Published in *Population and Environment*, Vol. 23(1).

Abstract

From a material and energetic perspective, this paper outlines the patterns of society-nature interactions, of a local horticultural, hunter-and-gatherer population inhabiting a remote island between India and Indonesia. Based on empirical research, we present several indicators to show an economic portfolio of a local society that combines horticulture, hunting and gathering activities with elements of industrialisation and market economy. In describing these environmental relations, the study narrows its focus to the use of three socio-ecological concepts, namely socio-economic metabolism, colonising natural processes, and the energetic return on investment. Using these concepts, we show the dynamics of social and environmental transformation at a local level and the consequences this may have for sustainability.

Appendix 2: Prints of excel templates (blank)

POPULATION STOCKS

	Male				Female				Total population				Nr. of Households
									Male	%	Female	%	
	0-5	6-15	16-60	> 60	0-5	6-15	60	> 60					
Population fraction													
Please specify													
Please specify													
Please specify													
Economic activities													
Agriculture													
Non-Agriculture													
Please specify													
Please specify													
Please specify													
TOTAL													

POPULATION FLOWS

		Male	Female	Total	Population dynamics
Birth					
	Specify year				
	Specify year				
	Specify year				
Death					
	Specify year				
	Specify year				
	Specify year				
Emigration					
	Specify year				
	Specify year				
	Specify year				
Immigration					
	Specify year				
	Specify year				
	Specify year				
TOTAL					

Activity code and classification

SL	Sleeping
ET	Eating
HY	Hygiene
ID	Rest and Idleness
LE	Leisure Activities
SC	Study and Education
CC	Care fod Dependents
FP	Food Preparation
HB	House Building
MR	Repair/Maintenance Work
D	Various domestic chores
FT	Fetching water
FW	Collecting firewood, preparing firewood
WA	Washing (laundry, pots)
AC	Agriculture and horticulture
H	Hunting
F	Fishing
G	Gathering
TD	Trading
W	Wage work
HG	Housegarden
MT	Handicraft
AN	Animal Husbandry
PL	Public Sports and Games
VS	Visiting Friends and Relatives
RI	Ceremonies and Festivals
PO	Community & Political Participation
CW	Communal work/engagement

	Name of local rural system											
	Males						Females					
	Total	Children, Age 0-15	SD (boys)	Adults, Age 16-60	SD (adults)	Adults, Age >60	Total	Children, Age 0-15	SD (girls)	Adults, Age 16-60	SD (adults)	Adults, Age >60
Number of inhabitants												
Sample size (n)												
Person System												
Sleeping												
Eating												
Hygiene												
Rest and Idleness												
Leisure Activities												
Studying & Education												
Subtotal		0,0		0,0		0,0		0,0		0,0		0,0
Household System												
Care for Dependants												
Food Preparation												
House Building												
Repair/Maintainance Work												
Domestic Chores												
Subtotal		0,0		0,0		0,0		0,0		0,0		0,0
Economic System												
Agriculture/ Horticulture												
Hunting												
Fishing												
Gathering												
Trading												
Wage Work												
Kitchen garden												
Handicraft												
Animal Husbandry												
Subtotal		0,0		0,0		0,0		0,0		0,0		0,0
Community System												
Public Sports and Games												
Visiting friends and relatives												
Ceremonies & Festivals												
Community & Political Participation												
Subtotal		0,0		0,0		0,0		0,0		0,0		0,0
TOTAL		0		0		0		0		0		0

LAND COVER AND LAND USE [hectares]

fill in the green cells

Land cover classes	Land use types	Hectares	%
Woodland			
	Woodland for wood production		
	Grazed woodland/shrubland		
	Succession woodland in shifting cultivation (more than one year fallow)		
	Woodland not used for grazing and wood extraction		
	Subtotal	0	
Grassland			
	Meadows		
	Cultivated pastures		
	Rough grazing		
	Subtotal	0	
Cropland			
	Cereals		
	Roots, tubers		
	Sugar crops		
	Pulses		
	Oil bearing crops		
	Vegetables		
	Fibres		
	Other crops (specify)		
	Fallow (less than one year)		
	Subtotal	0	
Permanent cultures			
	Orchards, vineyards, palmtrees - please specify		
	Subtotal	0	
Built up land			
	Transport infracstructure (roads etc.)		
	Buildings		
	Other		
	Subtotal	0	
Waterbodies (*incl. swamps, mangroves, coastal zones*)	Specify		
	Subtotal	0	
Non-productive land			
	Specify		
	Subtotal	0	
	TOTAL	0	0

LIVESTOCK

	Number	[kg/animal] Average weight	Total weight
Cows			0
Other cattle			0
Buffaloes			0
Horses			0
Asses, mules			0
Pigs			0
Sheep			0
Goats			0
Camels			0
Chicken			0
Other poultry			0
TOTAL	0	0	0

BIOMASS FLOWS [tonnes]

			Extraction/ Production	Import	Export	Con-sumption (DMC)	Food	Feed	Energy generation	Other use (seed, losses, etc.)
Primary production										
	Primary crops									
		Cereals				0				
		Roots, tubers				0				
		Sugar crops				0				
		Pulses				0				
		Nuts				0				
		Oil bearing crops				0				
		Vegetables				0				
		Fruits				0				
		Fibres				0				
		Other crops (Spices, stimulant crops etc.)				0				
		Subtotal	0	0	0	0	0	0	0	0
	Crop residues (used)									
		Straw				0				
		Other crop residues				0				
		Subtotal	0	0	0	0	0	0	0	0
	Fodder crops incl. grassland harvest									
		Fodder crops				0				
		Biomass harvested from grassland				0				
		Subtotal	0	0	0	0	0	0		
	Wood									
		Timber (Industrial roundwood)				0				
		Wood fuel and other extraction				0				
		Litter				0				
		Subtotal	0	0	0	0	0	0	0	0
	Fishing, hunting & gathering									
		Please specify				0				
		Subtotal	0	0	0	0	0	0	0	0
Secondary production										
	Animal products									
		Milk				0				
		Meat				0				
		Eggs				0				
		Other				0				
		Subtotal	0	0	0	0	0	0	0	0

MINERAL MATERIALS: FLOWS and STOCKS [tonnes]

	flows			stocks
	extraction	imports	exports	
Metals				
Non metalic minerals				
Fossil energy carriers	0	0	0	0
Soft coal				
Hard coal				
Petroleum				
Natural gas				
Other products				

OVERVIEW MATERIAL FLOWS [tonnes]

	Domestic extractic	Imports	Exports	DMC
Agricultural biomas	0	0	0	0
Wood	0	0	0	0
Metals	0	0	0	0
Non metallic minera	0	0	0	0
Fossil energy carrie	0	0	0	0
Other products and	0	0	0	0
Total	**0**	**0**	**0**	**0**

ENERGY FLOWS [Giga joules]

	Extraction	Import	Export	DEC
Agricultural biomass	-	-	-	-
Forest biomass	-	-	-	-
Coal	-	-	-	-
Petroleum products	-	-	-	-
Natural gas	-	-	-	-
Electricity				-
Solar heat and other energy generation				-

Notes:
Conversion of kWh into GJ: kWh*3.6/1000

Appendix 3: Exemplary excel templates (filled)

MATERIAL FLOWS COMPARED ACROSS CASES IN INDIA, BOLIVIA, LAOS, THAILAND, AND AUSTRIA

		THINKET 2000 (INDIA)			CAMPO BELLO 2004 (BOLIVIA)			NALANG 2001 (LAOS)		
		Total [tons]	[tons/capita]	[tons/ha]	Total [tons]	[tons/capita]	[tons/ha]	Total [tons]	[tons/capita]	[tons/ha]
1.	Domestic Extraction (DE)	2314,2	5,8	0,6	427,9	1,9	0,7	2022,8	2,9	1,2
	Biomass	917,7	2,3	0,25	427,77	1,85	0,70	2022,8	2,9	1,24
	Minerals	1396,5	3,5	0,38	0,00	0,00	0,00	0,0	0,0	0,00
	Fossil energy carriers	0,0	0	0,00	0,00	0,00	0,00	0,0	0,0	0,00
2.	Imports	138,65	0,35	0,04	26,01	0,12	0,04	78,4	0,1	0,05
	Biomass	39,00	0,10	0,01	19,76	0,09	0,03	5,0	0,0	0,00
	Minerals	79,00	0,20	0,02	1,06	0,01	0,00	19,3	0,0	0,01
	Fossil energy carriers	15,00	0,04	0,00	0,74	0,00	0,00	8,7	0,0	0,01
	Products	3,00	0,01	0,00	4,45	0,02	0,01	40,4	0,1	0,03
3.	Domestic Material Input (DMI)	2453,05	6,2	0,7	453,9	2,0	0,7	2099,2	3,0	1,3
	Biomass	957,60	2,40	0,26	447,53	1,94	0,73	2027,8	2,9	1,24
	Minerals	1476,30	3,70	0,41	1,06	0,01	0,00	19,3	0,0	0,01
	Fossil energy carriers	15,00	0,04	0,00	0,74	0,00	0,00	8,7	0,0	0,01
	Products	3,00	0,01	0,00	4,45	0,02	0,01	40,4	0,1	0,03
4.	Exports	968,57	2,4	0,3	86,1	0,4	0,1	207,1	0,4	0,2
	Biomass	51,87	0,1	0,01	85,85	0,37	0,14	200,4	0,4	0,17
	Minerals	917,70	2,3	0,25	0,00	0,00	0,00	0,0	0,0	0,00
	Fossil energy carriers	0,00	0,0	0,00	0,00	0,00	0,00	0,0	0,0	0,00
	Products	0,00	0,0	0,00	0,00	0,00	0,00	0,0	0,0	0,00
	Livestock	0,00	0,0	0,00	0,25	0,00	0,00	6,7	0,0	0,00
5.	Domestic Material Consumption (DMC)	1484,28	3,7	0,4	367,7	1,6	0,6	1912,1	2,6	1,1
	Biomass	905,73	2,3	0,2	361,7	1,6	0,6	1747,4	2,5	1,07
	Minerals	558,60	1,4	0,2	1,1	0,0	0,0	19,3	0,0	0,01
	Fossil energy carriers	15,00	0,04	0,0	0,74	0,00	0,0	8,7	0,0	0,01
	Products	3,00	0,01	0,0	4,45	0,02	0,0	40,4	0,1	0,03
	Livestock	0,00	0,00	0,0	-0,25	0,00	0,0	-6,7	0,0	0,00

		SANG SAENG 1999 (THAILAND)			THEYERN (Austria) 1830			THEYERN (Austria) 2001		
		Total [tons]	[tons/capita]	[tons/ha]	Total [tons]	[tons/capita]	[tons/ha]	Total [tons]	[tons/capita]	[tons/ha]
1.	Domestic Extraction (DE)	485,9	2,9	2,7	591,4	5,7	0,0	756,0	12,0	9,9
	Biomass	485,90	2,90	2,7	591,4	5,7		756,0	12,0	9,9
	Minerals	0,00	0,00	0,0	0,0	0,0		0,0		0,0
	Fossil energy carriers	0,00	0,00	0,0	0,0	0,0		0,0	0,0	0,0
2.	Imports	256,50	1,50	1,4	0,0	0,0	0,0	211,7	3,4	2,9
	Biomass	34,20	0,20	0,2	0,0	0,0		88,5	1,4	1,2
	Minerals	119,70	0,70	0,7	0,0	0,0		18,9	0,3	0,2
	Fossil energy carriers	17,10	0,10	0,1	0,0	0,0		88,2	1,4	1,2
	Products	85,50	0,50	0,5	0,0	0,0		16,4	0,3	0,2
3.	Domestic Material Input (DMI)	752,40	4,40	4,1	591,4	5,7	0,0	967,7	15,4	12,7
	Biomass	530,10	3,10	2,9	591,4	5,7		844,5	13,4	11,1
	Minerals	119,70	0,70	0,7	0,0	0,0		18,9	0,3	0,2
	Fossil energy carriers	17,10	0,10	0,1	0,0	0,0		88,2	1,4	1,2
	Products	85,50	0,50	0,5	0,0	0,0		16,4	0,3	0,2
4.	Exports	136,80	0,80	0,7	25,5	0,3	0,0	509,2	8,4	7,0
	Biomass	136,80	0,80	0,7	20,4	0,2		509,2	8,4	7,0
	Minerals	0,00	0,00	0,0	5,1	0,1		0,0		0,0
	Fossil energy carriers	0,00	0,00	0,0	0,0			0,0		0,0
	Products	0,00	0,00	0,0	0,0			0,0		0,0
	Livestock	0,00	0,00	0,0	0,0					
5.	Domestic Material Consumption (DMC)	615,60	3,60	3,3	565,9	5,5	0,0	458,5	7,0	5,8
	Biomass	393,30	2,30	2,1	581,0	5,5		315,0	5,0	4,1
	Minerals	119,70	0,70	0,7	-5,1	-0,1		18,9	0,3	0,2
	Fossil energy carriers	17,10	0,10	0,1	0,0	0,0		88,2	1,4	1,2
	Products	85,50	0,50	0,5	0,0	0,0		16,4	0,3	0,2
	Livestock	0,00	0,00	0,0	0,0	0,0				

ENERGY FLOWS COMPARED ACROSS CASES IN INDIA, BOLIVIA, LAOS, THAILAND, AND AUSTRIA

			TRINKET 2000 (INDIA)			CAMPO BELLO 2005 (BOLIVIA)			NALANG 2001 (LAOS)		
			Total [GJ]	[GJ/cap/yr]	[GJ/ha]	Total [GJ]	[GJ/cap/yr]	[GJ/ha]	Total [GJ]	[GJ/cap/yr]	[GJ/ha]
1.	Domestic Extraction (DE)		11.970	30,0	3,3	5.583	24,2	9,1	21.208	30,2	13,0
		Biomass	11.970	30,0	3,30	5.583	24,17	9,08	21.208	30,21	13,01
		Fossil energy carriers	0	0	0,00	0	0,00	0,00	0	0,00	0,00
		Electricity									
		Solar energy and other									
2.	Imports		1.197	3,00	0,33	319	1,38	0,52	618	0,88	0,38
		Biomass	439	1,10	0,12	289	1,25	0,47	339	0,48	0,21
		Fossil energy carriers	758	1,90	0,21	30	0,13	0,05	279	0,40	0,17
		Electricity	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
		Solar energy and other									
3.	Direct Energy Input (DEI)		13.167	33,0	3,6	5.902	25,5	9,6	21.826	31,1	13,4
		Biomass	12.409	31,10	3,42	5.872	25,40	9,55	21.547	30,69	13,22
		Fossil energy carriers	758	1,90	0,21	30	0,13	0,05	279	0,40	0,17
		Electricity	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
		Solar energy and other									
4.	Exports		1.397	3,5	0,4	1.127	4,9	1,8	3.382	4,8	2,1
		Biomass	1.397	3,5	0,39	1.127	4,88	1,83	3.382	4,82	2,07
		Fossil energy carriers	0	0,0	0,00	0	0,00	0,00	0	0,00	0,00
		Electricity	0	0,0	0,00	0	0,00	0,00	0	0,00	0,00
		Solar energy and other									
5.	Domestic Energy Consumption (DEC)		11.771	29,5	3,2	4.775	20,7	7,8	18.445	26,3	11,32
		Biomass	11.012	27,6	3,04	4.745	20,54	7,72	18.166	25,88	11,14
		Fossil energy carriers	758	1,90	0,21	30	0,13	0,05	279	0,40	0,17
		Electricity	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00
		Solar energy and other									

			SANG SAENG 1999 (THAILAND)			THEYERN (Austria) 1830			THEYERN (Austria) 2001		
			Total [GJ]	[GJ/cap/yr]	[GJ/ha]	Total [GJ]	[GJ/cap/yr]	[GJ/ha]	Total [GJ]	[GJ/cap/yr]	[GJ/ha]
1.	Domestic Extraction (DE)		7.011	41,0	38,1	7.932	77,8	35,3	6.727	108,9	88,5
		Biomass	7.011	41,00	38,10	7.932	77,8	35,3	6.719	108,7	88,4
		Fossil energy carriers	0	0,00	0,00						
		Electricity									
		Solar energy and other							8	0,1	0,1
2.	Imports		1.139	6,66	6,19	0	0,0	0,0	5.745	93,2	75,6
		Biomass	501	2,93	2,72				1.293	20,5	17,0
		Fossil energy carriers	581	3,40	3,16				3.768	59,8	49,6
		Electricity	57	0,33	0,31				684	10,9	9,0
		Solar energy and other									
3.	Direct Energy Input (DEI)		8.150	47,7	44,3	7.932	77,8	35,3	12.472	199,0	164,1
		Biomass	7.512	43,93	40,83	7.932	77,8	35,3	8.012	127,2	105,4
		Fossil energy carriers	581	3,40	3,16				3.768	59,8	49,6
		Electricity	57	0,33	0,31				684	10,9	9,0
		Solar energy and other							8	0,1	0,1
4.	Exports		1.216	7,11	6,61	254	2,5	1,1	4.388	69,7	57,7
		Biomass	1.216	7,11	6,61	254	2,5	1,1	4.388	69,7	57,7
		Fossil energy carriers	0	0,00	0,00						
		Electricity	0	0,00	0,00						
		Solar energy and other									
5.	Domestic Energy Consumption (DEC)		6.934	40,55	37,69	7.678	75,3	34,1	8.084	128,3	106,4
		Biomass	6.296	36,82	34,22	7.678	75,3	34,1	3.624	57,5	47,7
		Fossil energy carriers	581	3,40	3,16				3.768	59,8	49,6
		Electricity	57	0,33	0,31				684	10,9	9,0
		Solar energy and other							8	0	0,1

Time Use: Examples from Trinket (India), Campo Bello (Bolivia) and Nalang (Laos)

Daily hours	Average adult 16-60			Average inhabitant		
	Trinket[1]	Campo Bello[2]	Nalang[3]	Trinket	Campo Bello	Nalang
Population size	244	91	356	399	231	702
Number children 0-15				155	137	318
Person System	18.45	13.21	14.34	20.33	18.18	18.33
Sleeping		7.90	7.82		10.28	9.48
Eating		1.59	1.17		2.19	1.59
Hygiene		0.77	0.59		1.21	0.91
Rest and Idleness		2.43	0.95		2.10	2.12
Leisure Activities		0.14	3.37		1.50	2.50
Studying & Education	0.00	0.16	0.44	0.25	0.90	1.73
Household System	3.23	3.79	3.68	2.14	2.11	2.13
Care for Dependents	0.00	1.59	0.46	0.00	0.84	0.25
Food Preparation	1.09	1.07	0.69	0.72	0.48	0.46
House Building	0.00	0.26	1.43	0.00	0.10	0.78
Repair/Maintainance Work	0.16	0.34	0.00	0.11	0.24	0.00
Domestic Chores	1.98	0.64	1.10	1.31	0.45	0.63
Economic System	1.19	4.69	5.85	0.79	2.46	3.47
Agriculture/ Horticulture	0.07	2.53	3.06	0.06	1.08	1.83
Animal Husbandry	0.14	0.02	0.61	0.09	0.05	0.35
Hunting	0.03	0.46	0.00	0.00	0.26	0.00
Fishing	0.55	0.35	0.44	0.38	0.28	0.24
Gathering	0.02	0.17	0.15	0.00	0.22	0.11
Trading	0.39	0.43	0.00	0.25	0.19	0.00
Wage Work	0.00	0.27	1.46	0.00	0.10	0.87
Handicraft	0.00	0.41	0.13	0.00	0.29	0.07
Community System	1.13	2.32	0.12	0.75	1.25	0.06
Public Sports and Games	0.34	0.09	0.00	0.23	0.34	0.00
Visiting friends and relatives	0.49	1.56	0.00	0.32	0.66	0.00
Ceremonies & Festivals	0.30	0.39	0.12	0.20	0.14	0.06
Community & Political Participation	0.00	0.27	0.00	0.00	0.10	0.00
TOTAL	24.00	24.01	24.00	24.00	24.00	24.00
daily working time household + economic system	4.42	8.48	9.54	2.92	4.57	5.60

[1] For Trinket, a different method was used. Certain activities were observed repeatedly (sample size 3-5 each activity) and records were made how long they lasted and who (in terms of gender and age) participated in them. These activities were then weighted according to their annual frequency and thus the average daily hours could be calculated. The activities recorded were: changing the roof of a house (in detail), copra production (in detail), pig rearing (in detail), fishing and ceremonies (preparation and participation). For the household activities interviews were conducted. Time use for the person system was calculated as a residual.

[2] In Campo Bello, the latest of our case studies, the time use analysis was done most systematically, on the basis of observing people for days during their waking hours. The sample consisted of 12 male and 13 female days (containing 4 children between the age of 6-15 each). Adding to these samples, a total of 112 spot checks were carried out, thereby obtaining two more person days. Standard deviations for adults amounted to 1,5 hrs for the person system, 3,2 hrs for the household system, 1,9 hrs for the economic system and 5,6 hrs for the community system. This high variability is substantially reduced to within gender-homogenous samples.

[3] In Nalang, sample size was 23 females (among them: 10 girls) and 23 males (among them 11 boys). Standard deviations for adults amounted to 3,0 for the person system, 3,5 for the household system, 3,6 for the economic system and 0,6 for the community system, a variability that was not reduced by differentiating according to gender.

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