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# Material Flow Accounting in Amazonia
# A Tool for Sustainable Development

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**Abstract**

This report presents experiences from a research project carried out by members of IFF-Social Ecology in conjunction with researchers from Brazil, Venezuela, Colombia, and Bolivia. It demonstrates the application of Material Flow Accounting (MFA) tools in the region of Amazonia. The tools are tested for their ability to generate data in a series of cases, but also for their explanatory power of making a meaningful contribution to information systems on sustainability in the region.

The concept and approach are briefly discussed, followed by a lengthy presentation of research results and data gaps for each of the studies.

The research follows a multi-level approach by applying the MFA methodology to the national level as well as to local-level case-studies. While both perspectives generate results in their own right, the combination of insights leads to a fuller understanding of issues involved when assessing sustainability policies in such a diverse area. While national studies provide structural reasons for the relative de-linking of material intensity and industrial growth in wealthy nations, Amazonian economies are identified as *extractive economies*, structurally unable to decrease exporting materially intensive raw materials.

Local-level studies investigate micro-structures producing their own sustainability issues. Subsistence societies coping with rapid change and approaching industrialization show distinct characteristics in their material resource management, depending on respective histories, geographical place or position in the wider national/political economy.

Keywords: material flow accounting, sustainability, Amazonia

## Table of Contents

## FOREWORD

Can material flow accounting inform policies of sustainable development? Or, put in a more humble way, does it provide systematic clues to identify particular risks and opportunities of sustainability? At the onset of this project, it was felt that the analysis of socio-economic metabolism, and the tools of material flow analysis, could prove to be particularly useful for understanding the potentials of sustainability for developing countries: within one approach, they provide a perspective both on the economy (namely its physical dimension), and on the pressures upon the environment resulting from economic activity. While both European partners and partners from PAC shared their hopes in the power of this approach, it was, internationally speaking, the first attempt to apply it to developing countries. At the beginning, it was fairly unclear whether, for those countries, sufficient and sufficiently reliable statistical data existed that could be used for this approach, nor was it clear whether the scientific capacity in PAC countries could be mobilized to handle it properly. On a substantial level, no specific hyptheses had yet been formulated as to what a more or a less sustainable metabolic profile of a developing country would look like. Thus, the attempt to apply MFA to PAC countries was a pioneer task world wide, and the goal explicitly set for our project was to test the applicability of MFA. As can be seen below, this test was in some countries more successful than we had dared to expect, and so we can come up with some substantial results on the particular metabolic profile, and developmental trends, of PACs.

## 1 CONCEPTUAL AND METHODOLOGICAL FRAMEWORK

With the notion of sustainability gaining influence in the environmental discourse, the features of this discourse have changed remarkably. No longer was it the toxicity of particular substances that was seen as the main problem of society's pressure upon the environment. The focus moved from the output side of the production system to a comprehensive understanding of the physical dimension of the economy. Increasingly, the economy was conceptualized as a set of activities extracting materials from nature, transforming them, keeping them as society's stock for a certain amount of time and, at the end of the production-consumption chain, disposing of them again in the natural environment. It has been recognised that environmental problems can arise at every step in this process. Furthermore, it has been understood that it may be not only problematic substances but also problematic amounts of matter set in motion by society's activies that result in global environmental problems (Schandl and Weisz 2000).

### 1.1 SOCIO-ECONOMIC METABOLISM AND MATERIAL FLOW ACCOUNTING (MFA)

How much energy and matter, and which materials socio-economic systems draw from their environments, and how they transform these materials, largely depends on their historical mode of subsistence, and this, in turn, is closely related to technology. One can describe a „characteristic metabolic profile“ for each mode of subsistence, and overall historical changes are associated with substantive changes in socio-economic metabolism (Fischer-Kowalski et al. 1997). This implies substantive changes in resource utilization on the input side, and substantive changes in pollution problems on the output side. In interaction with specific natural environments, sustainability problems therefore also change.

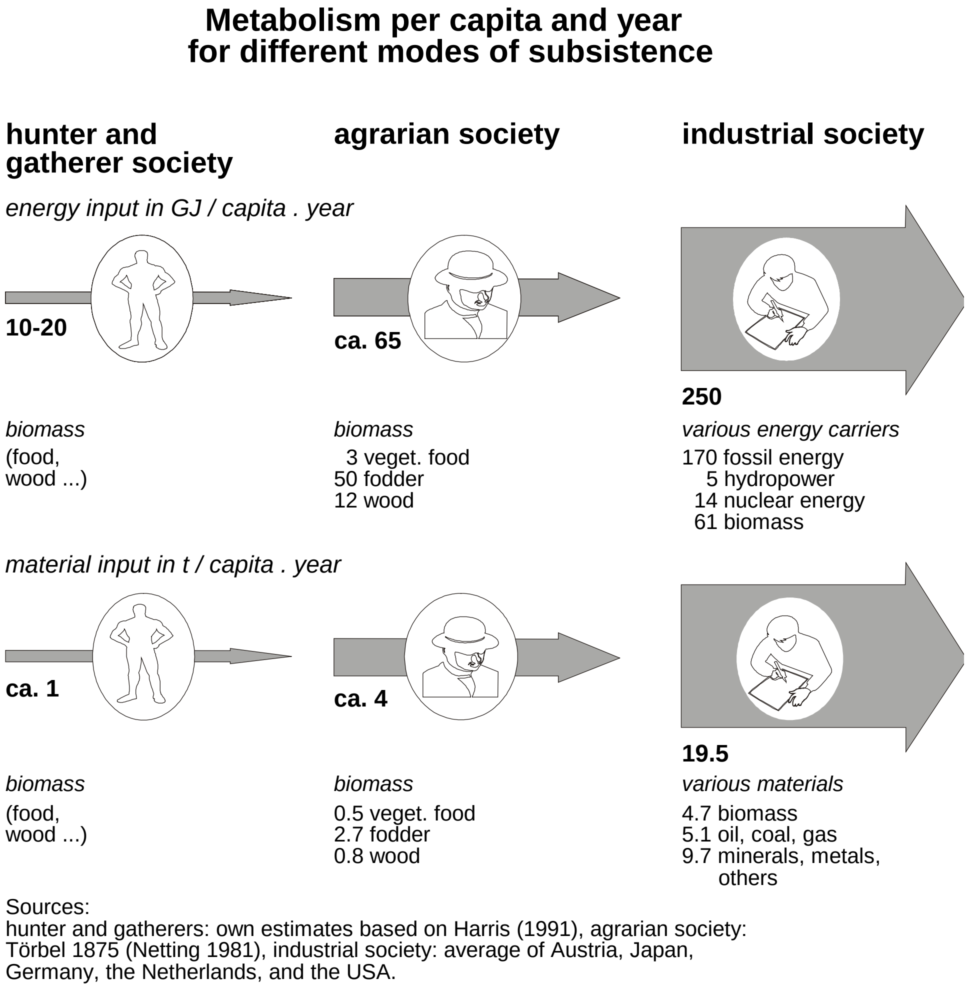


*Figure 1.* ***Characteristic metabolic profiles***

Socio-economic metabolism refers to the sum total of the material and energetic flows into, within and out of a socio-economic system. Socio-economic metabolism serves (a) to produce and reproduce the material elements of the socio-economic system (i.e. its physical compartments: humans, animal livestock, and durable goods) and (b) eventually to produce deliverables to other socio-economic systems (exported materials). Each socio-economic system has a territorially defined boundary towards other socio-economic systems, and a functionally defined boundary towards its natural environment.

Material flow accounting (MFA) can be regarded as a set of methods for describing and analyzing socio-economic metabolism. This presupposes a collective organization on the part of humans to maintain ways of life within a natural (and social) environment. Thus we are interested in examining socio-economic systems (such as national economies) as systems that reproduce themselves not only socially and culturally but also physically through a continuous exchange of energy and matter with their natural environments and with other socio-economic systems.

It should be understood that this methodology has been developed within the last decade, and that it is still „in development" although major steps were taken in harmonizing methodology (Adriaanse et al. 1997, Matthews et al. 2000, EUROSTAT 2001). This holds true for MFA on the level of national economies (NMFA), and even more so for local community MFA-studies (LMFA).

With LMFAs, the body of experiences extends from industrial towns (see Bacchini in Switzerland or Boyden (1981) in Hong Kong) to villages living from subsistence-agriculture in

India or Thailand. Still, each local mode of subsistence, and each local community culture, provides new methodological challenges.

Since the early 1990s, the MFA approach has been picked up on by many countries and often has been even introduced into their official statistics. Gradually, MFA was methodologically refined so as to eliminate inconsistencies that had hampered international comparability.

In the course of this refinement, it was specified that material flow analysis should comply to the following basic assumptions and conventions:

*(1) The law of „conservation of mass“*

Any MFA is based upon the idea of balancing, which originates from the law of conservation of mass:

Input = Output + Stock increases - Stock decreases

In words: The sum of material/energetic inputs into a system equals the sum of outputs plus stock increases minus stock decreases.

*(2) The metabolism of the socio-economic system is composed of the metabolisms of its compartments, namely the biophysical structures it contains. For each compartment, the law of conservation of mass also applies.*

This equation follows from a systems approach, looking at an economy or society as an integrated whole much in the way biology that sees an organism, examining its „metabolism“ as a highly interdependent self-organizing process rather than as just an assembly of „material flows“. Following this analogy, just as the metabolism of an organism is composed of the metabolism of each of its cells, so is the metabolism of a socio-economic system composed of the metabolism of each of its compartments.

*(3) Bio-physical compartments of socio-economic systems*

This notion requires the explicit specification of what is considered to constitute the compartments of the socio-economic system. For socio-economic systems on a national level, the most common convention is to consider *human bodies*, *animal livestock*, and *artifacts (durable goods)* as bio-physical compartments maintained by socio-economic metabolism as well as by collectively organized human labor.

To be consistent, the complete metabolisms *of the humans and of the animal livestock* must be included. This comprises nutrition, intake of oxygen and water, output of carbon dioxide and water, faeces, and the deposition of dead bodies. If livestock is included as a compartment of the social system, then meat and milk, etc. may of course not be treated as inputs from the environment but must be looked upon as transfers within the system.[1]

Finally, long-lived *artifacts* – i.e., human-made and human-maintained technical structures such as buildings, machines, vehicles and the like, but also roads, dams, or sewers – must be looked upon as physical compartments of socio-economic systems. This implies, according to equation (2), that all the materials used for making and maintaining these structures belong to the social system’s metabolism, as do the energy and the materials (such as water, air and various raw materials) used to make them function and to produce those goods and services for which the social system has constructed them.

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[1] Some approaches also consider *plants* as a compartment of the social system (Stahmer et al. 1997). If agricultural plants are considered to be part of the socio-economic system, the boundary between this system and its environment is „pushed outward“, to the mineral level, except for fishing, hunting and gathering. This does not correspond to any existing economic statistics, and besides it is difficult to distinguish between „social system plants“ and „natural plants“ (Fischer-Kowalski & Weisz 1999). So while the inclusion of plants may be warranted for some theoretical reasons – for example because agricultural plants are maintained by human labor just as livestock are – it is usually not considered practical.

*(4) Stocks and flows*

A reliable distinction between stocks and flows is a prerequisite for empirically determining whether a socio-economic system is still „growing“ (in physical terms), is in a steady state, or is shrinking. Stocks refer to the size of the population, the size of animal livestock, and the weight of the infrastructure. Accordingly, an operational distinction between „size“ and „metabolic rate“, as well as between the „growth rate“ and the energetic and material „turnover“ of the social system can be defined, and the indicator „net addition to stocks“ can be calculated.

*(5) Water, air and „other materials“*

Typically, three groups of input materials are distinguished: water, air, and the remaining input materials (consisting of biomass, fossil fuels, minerals, and manufactured products). Most MFA indicators are based on the „other materials“ only. This has to do with the common-sense idea of not literally „drowning“ economically valued raw materials and commodities in water and air.[2]

*(6) Direct materials input and indirect flows, „rucksacks“, or „hidden flows“:*

According to the conventions established so far, „direct materials input“ refers to the non-water-non-air fraction of materials that actually cross the boundary of a socio-economic system (see Figure 2). Beyond the boundaries of the socio-economic system, there occur material flows that may be seen as prerequisite to the materials input of the socio-economic system in question, even if these former material flows remain beyond its boundaries. In the Schmidt-Bleek (Wuppertal) tradition, these indirect material flows are termed „rucksacks“. One can distinguish between the rucksacks of imports and the rucksacks of domestic materials extraction. (Another expression used is „hidden flows”, see for example Adriaanse et al. 1997).[3]

*(7) Domestic processed output*

Domestic processed output (DPO) refers to the total of all materials used in the domestic economy (i.e., which result from direct material input) at the point where they flow back into the natural environment as wastes, emissions, or deliberate disposals (such as fertilizer). These outflows can also be distinguished according to the environmental media they enter (air, water, soil). When hidden flows within the domestic environment are also included, one refers to Total Domestic Output (TDO).

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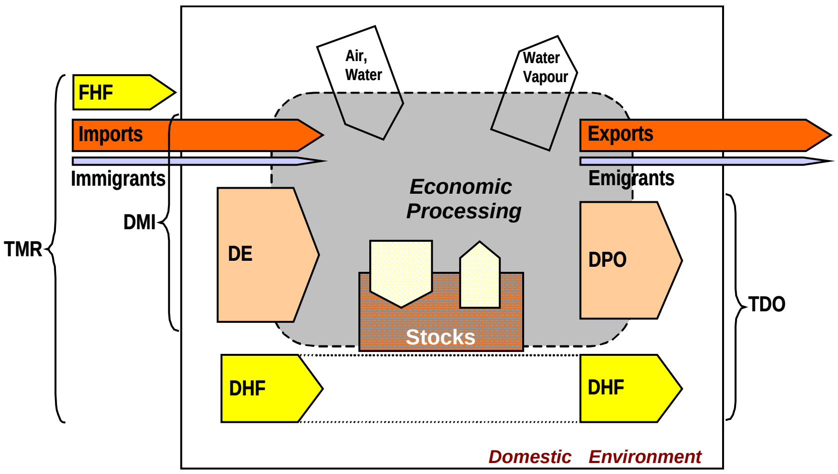
[2] In modern industrial economies, „other materials” amount to only about 5% of the overall material input, the rest is water and air (Fischer-Kowalski et al. 1997). However, the distinction becomes fuzzy upon closer examination, as the „non-water-non-air” fraction is not free of water and air. Moreover, the content of water and air of the various materials changes due to natural processes such as evaporation and oxidation, and also due to technical processes within the socio-economic system. For the calculation of a mass balance, these processes have to be taken into account. So far, the methods applied have proved to be not completely consistent (see for example the country reports in Matthews et al. 2000)

[3] Usually, these rucksacks comprise the non-water-non-air wastes and emissions that occurred during the production process of an imported good in the country of origin, and particularly large material flows that occur as side effects of domestic extraction (such as overburden in mining or eroded soil in agriculture). The sum of Direct Material Input and hidden flows has been termed „Total Material Requirement“ (TMR). Be aware it is not „total“ in the sense of including water and air! So far, there exists no term to signify the „grand total“ of all material flows including water and air crossing a system’s boundary. Among others, this terminological problem must still be resolved. When summing up or averaging TMR across countries, one must be aware that this involves double counting (namely, the hidden flows of imports).




DE: Domestic extraction
DHF: Domestic hidden flows
DPO: Domestic processed output
TMR: Total material requirement = DMI + DHF + FHF
DMI: Direct material input = DE + Imports
FHF: Foreign hidden flows
TDO: Total domestic output = DPO + DHF

*Figure 2.* ***The metabolism of a socio-economic system: The basic MFA model***

Source: Matthews et al. 2000, slightly modified

From this interrelated set of variables, several indicators can be drawn to represent a socio-economic system's impact upon the environment. On the one hand, these indicators may refer to the input side, following the argument that the more resources a system consumes, the more it is a burden to the environment (and the environment's future usability for other systems). Among these indicators, domestic extraction and „Direct Material Input" (DMI, equal to domestic extraction plus imports) will figure most prominently. Still another input-related indicator is „Domestic Material Consumption", DMC, which subtracts exports from DMI and so represents the amount of materials consumed by the system internally.

On the other hand, indicators may be chosen so as to refer not to the input but to the output (or rather, outflow) side, examples of the latter being DPO (Domestic Processed Output) and TDO (Total Domestic Output). If a socio-economic system (i.e., a national economy) has an even trade balance with imports equaling exports in terms of weight, and if it does not increase or decrease its stocks, then input should equal output over a certain time period. Practically, this is not the case for contemporary affluent industrial countries. So at the time being, DPO is much smaller than DMI, and resources (i.e., future wastes) are being accumulated within the socio-economic system (e. g., Matthews et al. 2000).

However, regardless of whether the *input* of resources or the *output* of wastes and emissions is at issue, we must ask whether the total weight of materials processed by a socioeconomic system is a viable indicator for „environmental impact" at all. All of the indicators mentioned are created by summing up the weights of many different materials. A few very large flows, such as those of construction minerals and fossil energy carriers on the input side or carbon dioxide on the outflow side, dominate these indicators, while smaller flows considered much more hazardous by environmental chemists are hardly evident. „Big flows are not automatically bad, and small flows are not automatically better" (Matthews et al. 2000, 2). Despite this consideration, one can say that all resource use involves environmental impact of some kind at every stage of the material cycle, from extraction or harvesting to final disposal. This means that unless technologies change, increases in resource input imply increases in environmental impacts. One should also consider that expert opinions since the beginning of the environmental debate have undergone quite extreme variations in answering the question of exactly which substances or processes should be seen as particularly environmentally harmful, while studies of the sum total of processed materials consistently tell their story in a reliable and uncontested way, even if it is only part of the whole story. A measure of processed materials represents a reasonable „headline indicator“ (Jesinghaus & Montgomery 1999) for the overall scale (Daly 1987) of anthropogenic systems *vis a vis* the natural environment, on the same level of generality as overall energy consumption or population numbers.

## 1.2 METHODOLOGICAL APPROACHES USED TO PROVIDE MFA'S FOR PAC

In task 2 of the Amazonia21 project we planned for two approaches of material flow accounting, based on the same conceptual framework, but working with different data collection technologies, namely Local Material Flow Accounting (LMFA) and National Material Flow Accounting (NMFA). Originally, it was planned to assess the applicability of material flow accounting within all four PACs participating (Bolivia, Brazil, Colombia, and Venezuela), encompassing three national MFA's, one regional MFA and one experimental local MFA. In the course of the experiences made, this original plan was modified. One major modification was to abandon the idea of „regional MFA's“: As became clear, the data availability on sub-national levels was not sufficient. More countries were willing to engage in local MFA-studies, instead. Finally, the following case studies were agreed upon and carried through (see Table 1):

| Country | Region | Type | Time period | Authors | Institution |
|---|---|---|---|---|---|
| **Bolivia** | | NMFA | 1995 – 1999 | A. Pierront | CIMAR |
| | ASPACH/El Chore | LMFA | | I. Lizarazú | CIMAR |
| **Brazil** | | NMFA | 1975 – 1995 | J. Machado | NAEA |
| | Caixuanã | LMFA | | K. Ninni, A. Mathis | NAEA |
| **Colombia** | Puerto Nariño | LMFA | | G. Ochoa, A. Wood | IMANI |
| **Venezuela** | | NMFA | 1988 – 1997 | H. Castellano | CENAMB |

*Table 1:* ***MFA Case studies: overview***

The basic idea of complementing MFA on a national level with local MFA data, which is not common when doing MFA for industrial countries, was the consideration that national accounting, in developing countries, does not give a full picture of the economy. A substancial fraction of people's sustainance activities may be expected to happen outside of (monetary) market economy. This fraction could be well represented with local MFA data, as can be seen from the case studies presented in chapter 3.

It would require an elaborate data processing and modeling beyond the scope of this project, though, to quantitively integrate the estimates from the local case studies on subsistence economy into the biophysical picture (MFA picture) generated from data reflecting the monetary economy as in national accounts.

# 2 APPLYING NATIONAL MATERIAL FLOW ANALYSIS IN PAC[4]

## 2.1 CORE QUESTIONS TO BE ANSWERED BY NMFA

There were two types of questions that task 2 in Amazonia21 was supposed to answer. The first type of questions referred to procedural and technical aspects of MFA. Was material flow analysis, a tool that had proven so influential in re-orienting the discussion on environmental impacts and sustainability, applicable to countries in Amazonia? Relevant aspects for answering this question are: Is there a sufficient data base (usually derived from economic statistics) to generate material flow data with a reasonable amount of effort, and with a reasonable degree of reliability? Is it possible to establish sufficiently qualified and motivated research teams in PACs to undertake this task? Will they find sufficient institutional support? And finally: is it possible to bridge the cultural, institutional and language differences between European and PAC scientists, and can PAC scientists be convinced of and empowered to apply, and in some respects re-invent, the MFA paradigm as originating from European sustainability science? Chapter 2.2 will seek to give answers to some of these questions.

The second type of questions refers to substantive aspects: Does, in quest for sustainability, MFA provide perspectives, and approaches to problem-solving, relevant for PACs? Does it help to structure insights into the combination of economic, social and environmental challenges these countries try to meet? Can it help to orient standards of sustainability, to prioritise environmental policy measures? Is it an adequate framework for making the specific complex situation of developing countries, in a particular environmental situation, better to be understood? In this report, we will tackle some of these questions, at best. If this project indeed was able to trigger the processes it should, we will see Latin America to become home to a rich tradition of MFA outside of Europe – but this will take some time.

## 2.2 THE RESEARCH PROCESS

At start, we were quite unsure how the cooperation of scientists from Europe and from PACs would work. Would there be sufficient research capacity and would available data fulfil the methodological requirements for MFA, as developed for industrial economies? Would the approach itself be convincing enough to motivate researchers from PACs to invest enough time and energy to generate reliable data? And, despite common knowledge of the literature, would cultural differences and differences in scientific working conditions hamper communication between researchers from Europe and partners in PACs? The whole research process was designed so as not to have researchers from Europe investigate PACs, but to guide researchers from those countries and enable them to make use of European experiences and apply them to their own conditions. But how was this to be achieved? As we found out during the process, the original design did not suffice. Differences in language, qualification, formal standing and research experience among our PAC partners required a more intensive and practical face-to-face-interaction between all partners to our task than we originally had expected. Thanks to the correct diagnosis of the situation by the coordinator of the PAC teams, who was willing and energetic enough to change pre-fabricated plans according to needs, and thanks to the flexibility on the part of the overall coordinator and the other European partners to follow his advice, several face-to-face interactions beyond the originally planned workshops could be organized.

A major step forward was the improvised workshop „train the trainer“ in Austria in June 1999 that helped to clarify conceptual and methodological problems. Furthermore, it supported the

[4] This chapter was written by Christof Amann of IFF – Social Ecology

generation of a base of mutual understanding and personal trust.[5] During this workshop, the scientists from Europe were thoroughly challenged by their PAC counterparts to explain the purpose of MFA, the possible interpretation of its results in terms of environmental and developmental consequences, and give good reasons for each methodological convention. This was key to establishing a good working relation.

Partners from PAC were asked to use the information they got at the „train the trainer" workshop to constitute an MFA team in their country and to work on MFA data by their own, seeking support from European partners via e-mail whenever needed. While in the consecutive months, e-mail was frequently used for sending data sheets and reports, comments on preliminary data sheets, on calculations, or on draft reports, but we made the experience that it was not a sufficient substitute for direct personal communication, particularly in the case of institutional, collaboration or motivation problems. Reactions on sent e-mails were not always clear, responses came very late sometimes and it was not clear if comments had been helpful for our partners in PAC. This gave rise to some unexpected delays, with the European partners starting to feel a little worried and helpless about how to further promote the process.

This situation was resolved by another spontaneous decision, supported by the coordinators and the PAC partners. It was decided that Christof Amann (IFF-Social Ecology) would pay an extended visit to each PAC team that had until then progressed to produce a preliminary NMFA report. This resulted in a most fruitful and productive part of the cooperation in March 2001, when he worked together side by side with Hercilio Castellano in Caracas/Venezuela and with Jose Alberto Machado in Manaus/Brazil. At that time preliminary NMFA data already existed, but it in the case of Venezuela there was a lack of clarity on the way how they had been collected, what sources had been used and how indicators had been calculated. In the case of Brazil, data seemed perfectly complete but system boundaries underlying the aggregations differed from international conventions. At the time that decision was made, no data from Bolivia had been delivered yet, so the Bolivian case could not be made part of this procedure. The collaborative effort resulted in NMFA data sets for Brazil (covering two decades) and Venezuela (covering one decade), the first data on developing countries worldwide that should perfectly meet international standards, and it confirmed a solid base for scientific cooperation in the future.

Using these data, M. Fischer-Kowalski and Ch. Amann did a preliminary analysis, comparing them with data from other countries, and made an attempt to understand the specific metabolic features of Brazil and Venezuela.[6] The results of this analysis were then, again in a spontaneous modification of procedures, thoroughly discussed and modified during a week of direct cooperation between M. Fischer-Kowalski as coordinator of task 2, N. Fenzl (as PAC-coordinator) and J. Machado in Manaos, and finally presented by the three authors to the international IHDP Open Science Meeting in Rio de Janeiro in October 2001.

## 2.3 RESULTS: METABOLIC PROFILES OF PACS

### NMFA Brazil

Originally, data for Brazil were collected by José Alberto Machado for his PhD thesis (Machado 1999), containing extensive documents on all data used and every step of data transformation. This dataset had to be adapted (Machado had used different system boundaries) to international standard conventions. Now NMFA data for Brazil can be classified as being international state of the art of material flow accounting. The latest revision was done using the EUROSTAT guide and therefore indicators as well as system boundaries and conventions comply to that source. The work of José Alberto Machado can

[5] Beyond that, it stimulated the production of a methodology guide to assist in following the same procedures across all case studies (see: http://www.univie.ac.at/iffsocec/amazonia21/)
[6] see Fischer-Kowalski and Amann 2001

be seen as an exemplary model of organizing data and – what is even more important – of a complete documentation of sources, contents of data etc. It is impressive of how an individual scientist can achieve so much despite lacking necessary literature on material flow accounting in Brazil and the lack of a methodological guide that could be used. This is even more impressive as MFA had been developed for and used in industrial countries only, and in Latin America there had existed hardly any scientific capacity to build upon. The Amazonia21 project demonstrated perfectly the benefits of international scientific cooperation for supporting existing scientific capacity in developing countries. Further discussion and research is still needed for non-market economy materials, data for grazing and for hidden flows which were calculated only for a few material categories only, due to missing factors.

### NMFA Venezuela

Data worked out in Caracas in March 2001 can be classified as comparable to EUROSTAT guide data (concerning DMI and DMC), except for natural gas which includes re-injection.[7] For comparison of data in this report we excluded the amounts re-injected, and arrive at numbers of net production (marketed production), as international statistics normally report on. Generally, data have a very high level of completeness. Non-market economy was partly estimated using factors from expert opinion. Domestic hidden flows were partly calculated in Caracas in March 2001, import and export hidden flows were then provided by Hercilio de Castellano but not being checked by us.

### NMFA Bolivia

The Bolivian project team provided a NMFA in time series from 1995 to 1999 (preliminary data for 1999), encompassing DMI, DMC, Population, and GNP. There is also a case study report available that documents used sources and calculations. Data are organized in a way that fits more or less to international conventions and the underlying system boundaries of the Bolivian MFA can be considered as more or less correct with the major exception of water and air uptake that should not be part of the derived indicators. Although the latest version of data show a remarkable increase in the quality of data and tables, the Bolivian data can not be used for comparison yet. DMI seems to be by far too low due to missing data on minerals and due to data of several materials where we have reason to question their quality. Hidden flows were not calculated at all. Problems mentioned by the project team were the lack of specific data and the conversion of units (coefficients).

### NMFA Indicators

| Indicators | Bolivia | Brazil | Venezuela |
|---|---|---|---|
| Domestic extraction DE | preliminary | available | available |
| Direct material input DMI | preliminary | available | available |
| Imports | preliminary | available | available |
| Exports | preliminary | available | available |
| Domestic material consumption DMC | preliminary | available | available |
| Hidden flows of DE | not available | partly available | available |
| Hidden flows of Imports | not available | not available | available/not checked |
| Hidden flows of Exports | not available | not available | available/not checked |
| Total material requirement TMR | not available | not available | available/not checked |

*Table 2:* ***NMFA indicators provided in the case studies***

[7] The data presented in the case study report, therefore, reflect the gross production of natural gas.

The following table gives an overview on the data. As mentioned above, data for Bolivia still have to be considered as preliminary. They will not be used for international comparison.

| | Brazil | Venezuela | Bolivia* | Unit |
|---|---|---|---|---|
| Domestic Extraction | 2,383,073 | 304,886 | 49,631 | 1,000 metric tons |
| Imports | 93,794 | 19,550 | 999 | 1,000 metric tons |
| Exports | 207,628 | 155,055 | 4,403 | 1,000 metric tons |
| Direct Material Input | 2,476,867 | 324,436 | 50,630 | 1,000 metric tons |
| Domenstic Consumption | 2,269,240 | 169,381 | 46,227 | 1,000 metric tons |
| | | | | |
| Population | 163,113 | 21,844 | 8,137 | 1,000 |
| GDP (PPP)** | 874,583 | 176,936 | 19,870 | 1,000.000 Int$ |
| GDP (PPP) per capita | 5,500 | 8,100 | 2,680 | Int$ |
| DMI per capita | 15.2 | 14.9 | 6.2 | metric tons |
| DMC per capita | 13.9 | 7.8 | 5.7 | metric tons |
| Material Intesity MI (DMI per unit GDP) | 2.83 | 1.83 | 2.55 | metric tons per 1,000 Int$ |
| Material Intesity MI (DMC per unit GDP) | 2.59 | 0.96 | 2.33 | metric tons per 1,000 Int$ |

* data do not meet international standards required for comparison

** data for GDP are different from those in the case studies where local currency units were used

*Table 3:* ***Data comparison 1995***

The following results refer to the data from Venezuela and Brazil only, both complying to the international state of the art. Data from Boliva have to be considered preliminary with the need of further clarification and re-calculations and therefore are not used for the conclusions.

## 2.4 THE METABOLIC PROFILE OF BRAZIL AND VENEZUELA, COMPARED INTERNATIONALLY

For the first time there is the chance to compare MFA data from developing countries with data from industrial countries.[8] The most interesting questions here are to find out if and where there are similarities in material flows and where there are differences. We do this using macro indicators like Direct Material Input (DMI) or Gross Domestic Product (GDP). An analysis of the data on the level of single material flows lies beyond the scope of this project but would nevertheless be an interesting field for further research. In a second step of data analysis we can ask for the reasons behind these similarities and differences and if there are interconnections between material flows in industrial and developing countries.[9]

[8] There are still some uncertainties that hamper full comparison. As some data for industrial countries were calculated before the EUROSTAT guide was published, they do partly not meet these standards. For developing countries, data for the subsistence economy had to be estimated rather roughly due to a lack of proper data sources. However, we would expect the overall picture as reasonably correct.

[9] The following analysis is discussed more extensively in Fischer-Kowalski and Amann 2001.

It comes as quite a surprise that material input (DMI) per capita in Brazil and Venzuela is much the same as it is in industrial countries (Figure 3). Since in Figure 1 we had been able to demonstrate that (historical) agrarian societies displayed a significantly lower material input than contemporary industrial societies, one would expect societies in transition from an agrarian to an industrial mode to lie somewhere in-between. This seems not to be the case for Brazil and Venezuela. If we subtract exports from DMI we get Direct Material Consumption (DMC). DMC in Brazil is quite the same as it is in industrial countries, but it is much lower in Venezuela.Therefore, DMC seems to have little power to reflect the particular situation of these two developing countries: one experiencing rapid change, the other having begun to export oil, and both being in the same situation of poverty for the mass of their inhabitants.

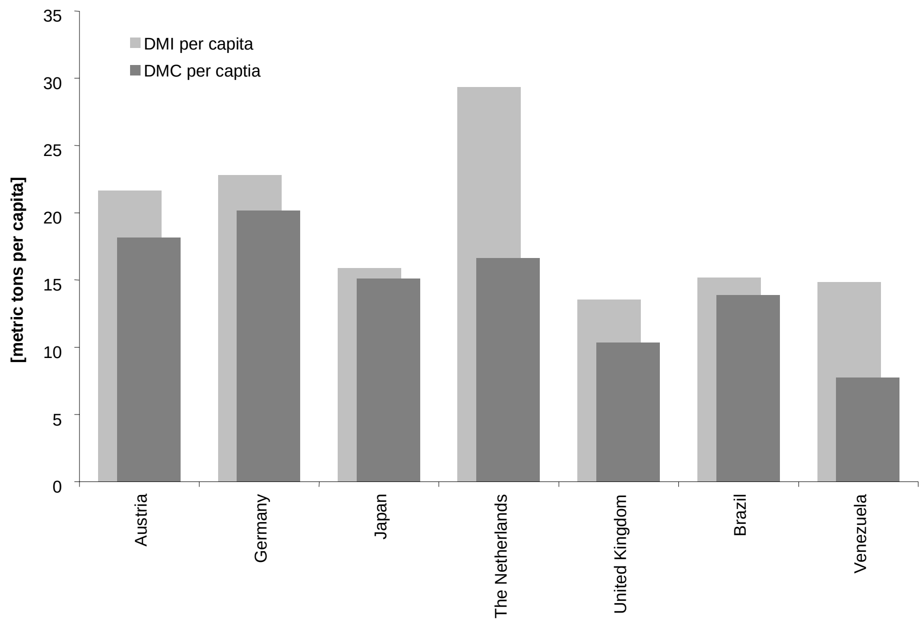



Figure 3: **Direct Material Input (DMI) and Domestic Material Consumption (DMC) of industrial countries, Brazil and Venezuela (1995)**

Sources: Adriaanse et al. 1997, Matthews et al. 2000, Schandl and Schulz 2001, Authors of Matthews et al. 2000 (pers. comm.), Amazonia21 (case studies)

And what about material intensity (MI = DMI/GDP)? Compared to industrial countries, GDP per capita calculated with purchasing power parities (PPP) in Brazil and Venezuela is very low (Figure 4). Both cases display a material intensity quite above that of the industrial core (Figure 5). Both Brazil and Venezuela have a large primary (and secondary) sector, producing raw materials and first stage products (such as pig iron)[10], selling them on the world market at a comparatively low price. Therefore, their material intensity is high. At the same time, their populations have a comparatively low standard of material comfort and therefore require a low material input serving domestic consumption (at a low price).

[10] see Fenzl & Monteiro 2000

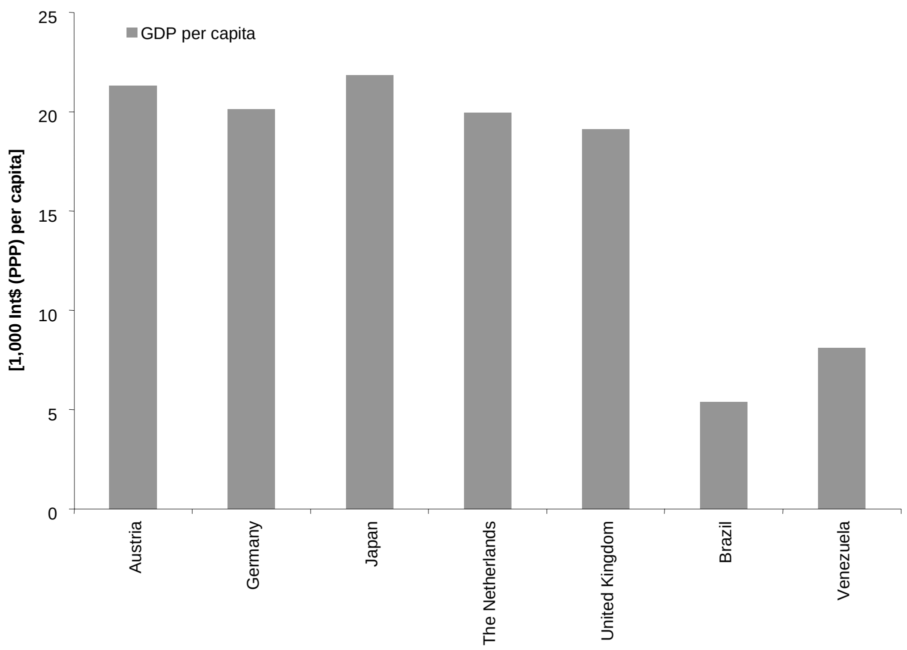



Figure 4: **Gross Domestic Product (GDP) of industrial countries, compared to Brazil and Venezuela (1995)**

Sources: World Resources Institute 1999 (data from World Bank)

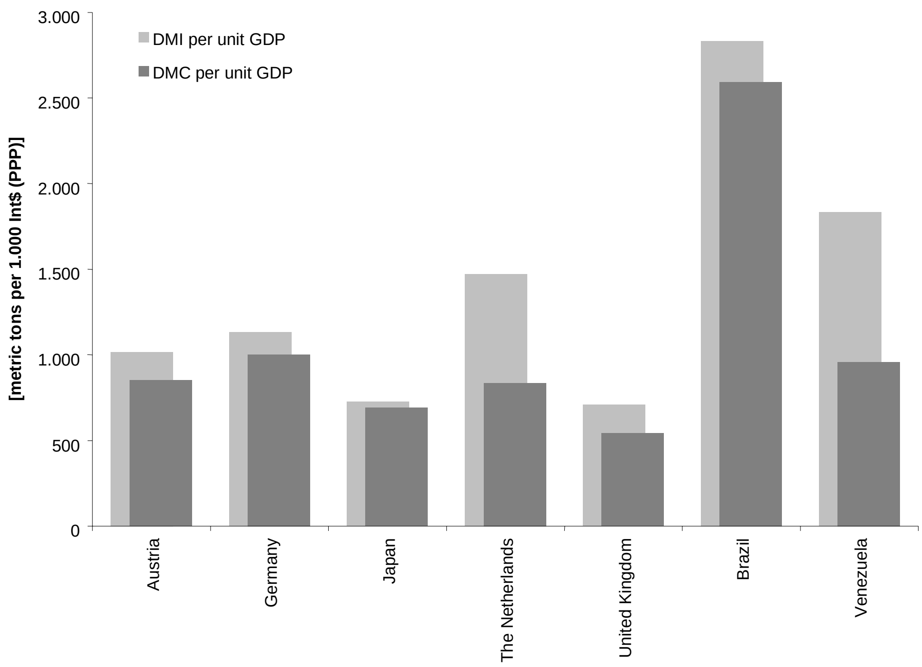



Figure 5: **Material Intensity (DMI per unit GDP, DMC per unit GDP) of industrial countries, compared to Brazil and Venezuela (1995)**

Sources: Adriaanse et al. 1997, Matthews et al. 2000, Schandl and Schulz 2001, Authors of Matthews et al. 2000 (pers. comm.), Amazonia21 (case studies), World Resources Institute 1999

If we now look at the time series of GDP, DMI, and MI (Figure 6), we can see that Brazil and Venezuela present a picture completely different from that in industrial countries. DMI grows more quickly than GDP, and material intensity is even rising – quite in contrast to the industrial core, where we have found GDP to be the fastest growing variable with a resultant decline in material intensity.

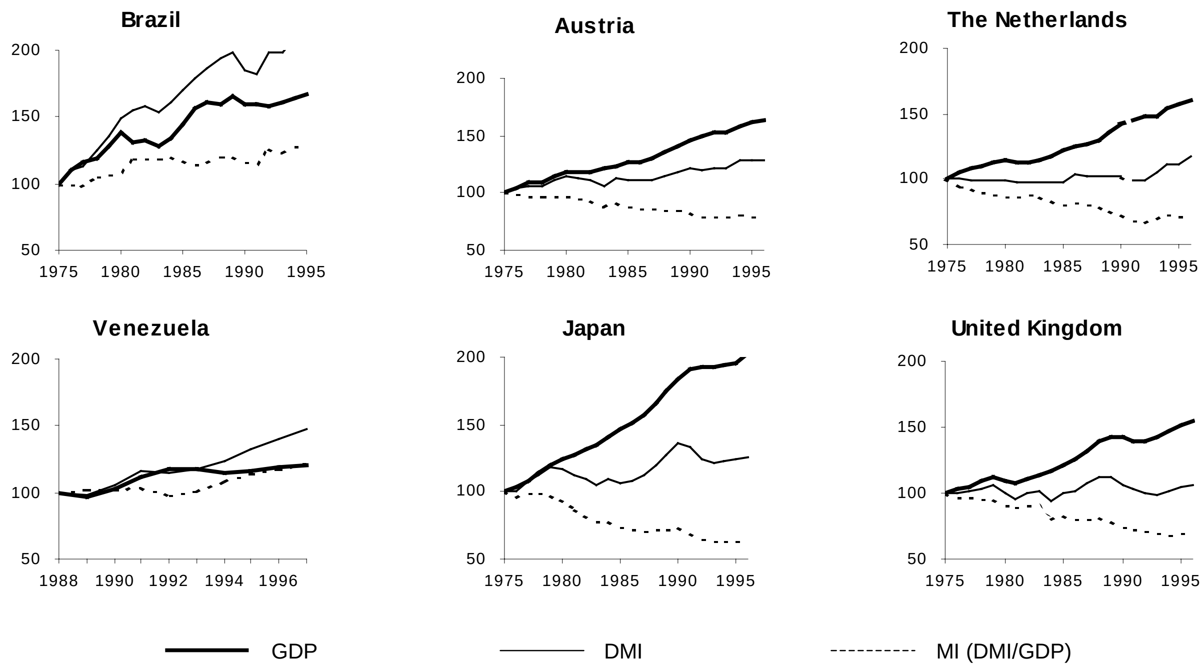



Figure 6: **Trends of Direct Material Input (DMI), Gross Domestic Production (GDP), and Material Intensity (MI) in industrial countries, Brazil and Venezuela (index, base year = 100).**

Sources: Adriaanse et al. 1997, Matthews et al. 2000, Schandl and Schulz 2001, Authors of Matthews et al. 2000 (pers. comm.), Amazonia21 (case studies), OECD

Our hypothesis here is that one of the reasons for this „relative" delinking of resource use and economic performance in industrial countries, while material intensity in developing countries seems to rise, is a result of the international division of labour. The most materially intensive processes of raw material extraction and industrial production are „externalized" to developing countries. These countries bear the main burden of the exploitation of their natural resources, as well as the burden of increasing domestic wastes and emissions for commodities largely consumed in industrial countries. At the same time, of course, the less affluent countries do gain in terms of income and domestic material consumption – but, it may be suspected, at a disproportionately lower rate.

Unfortunately, there is too little data to test this hypothesis systematically. We can gain some indications from a comparison of the material dimension of imports and exports of industrial countries with data on Brazil and Venezuela. If we look at the development of imports and exports in affluent industrial countries during the last two decades, we see them rise in proportion to the material input (DMI), as is to be expected from ordinary economic statistics. In terms of weight, all affluent industrial countries documented in the statistics import at least twice as much as they export (much of these imports being raw materials), and those exports rose steadily relative to the materials that were extracted domestically (Figure 7). Quite an opposite picture arises from the data on Brazil and Venezuela displayed in Figure 8. In these countries, exports exceed imports by a factor of 2 – 4 in terms of weight, and they are also growing steadily. Imports, on the other hand, are stagnating or even temporarily declining. So, as far as can be suspected on the basis of this very limited database, developing countries seem to be have been increasingly playing the role of suppliers of materially intensive processes and products for affluent countries throughout the last two decades. Such a scenario must automatically result in the reduction of domestic material intensity of inustrial countries, since imported commodities contribute to Direct Material Input (DMI) by their weight at crossing the borders, leaving behind in developing countries all the material loads involved in producing them.

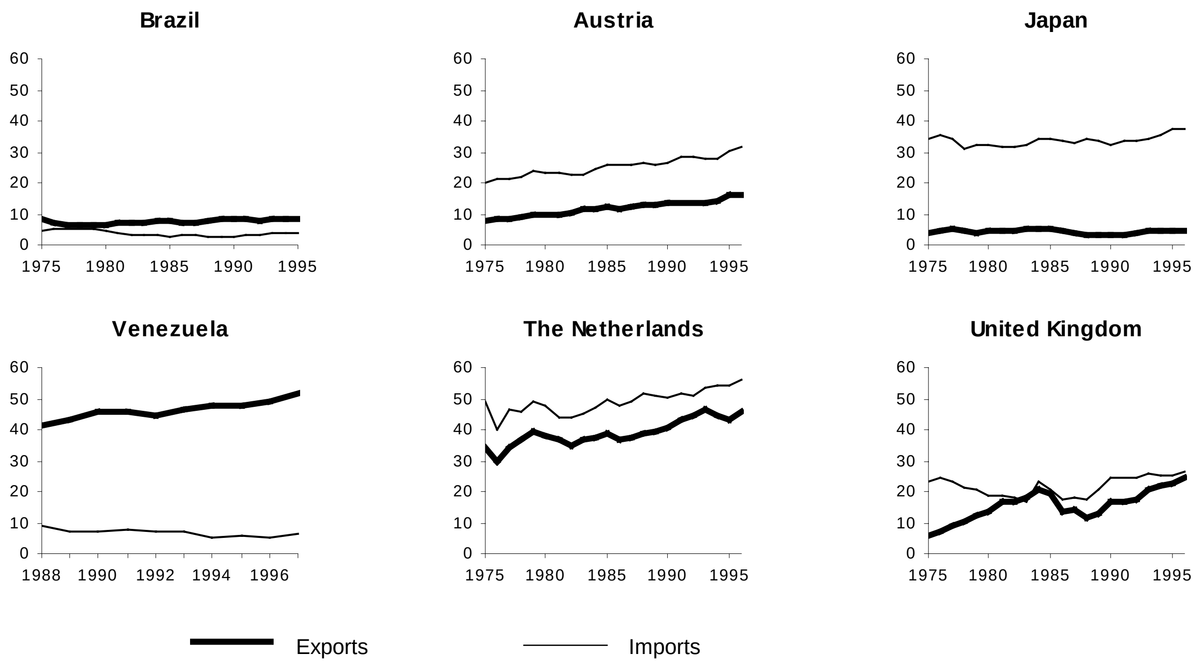



Figure 7: **Trends of Imports and Exports (%-share of DMI) in industrial coutries, compared to Brazil and Venezuela.**

Sources: Adriaanse et al. 1997, Matthews et al. 2000, Schandl and Schulz 2001, Authors of Matthews et al. 2000 (pers. comm.), Amazonia21 (case studies)

This is also documented by the Physical Trade Balance (PTB, Figure 8), representing the difference of imports and exports of a country in physical terms. Both Brazil and Venezuela export more materials than they import, while the opposite is true for industrial countries.

Looking at the material intensity of imports and exports we find another reference for our hypothesis. Material intensity of imports is high compared to material intensity of exports in industrial countries. On the other side, in Brazil and Venezuela, the material intensity of exports is very high (Figure 9). That means, not surprisingly, that industrial countries buy heavy weight and cheap raw materials and other goods at an early stage of manufacturing, while developing countries export these products at a low price while they have to deal with the environmental impacts associated with their extraction and primary production.

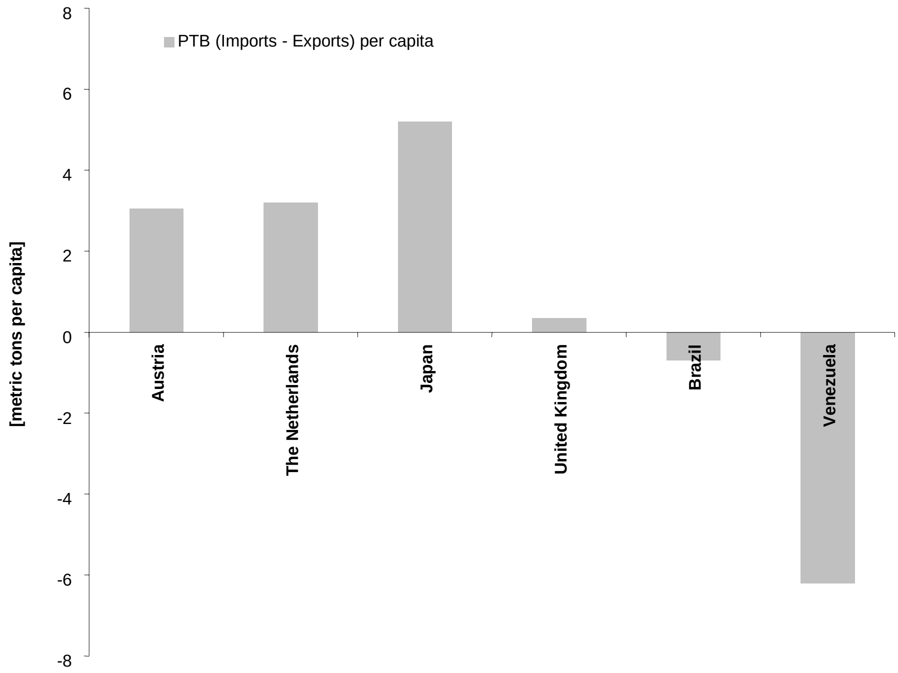



Figure 8: **Physical Trade Balance (PTB = imports - exports) of industrial countries, Brazil and Venezuela (1995)**

Sources: Matthews et al. 2000, Schandl and Schulz 2001, Authors of Matthews et al. 2000 (pers. comm.), Amazonia21 (case studies)

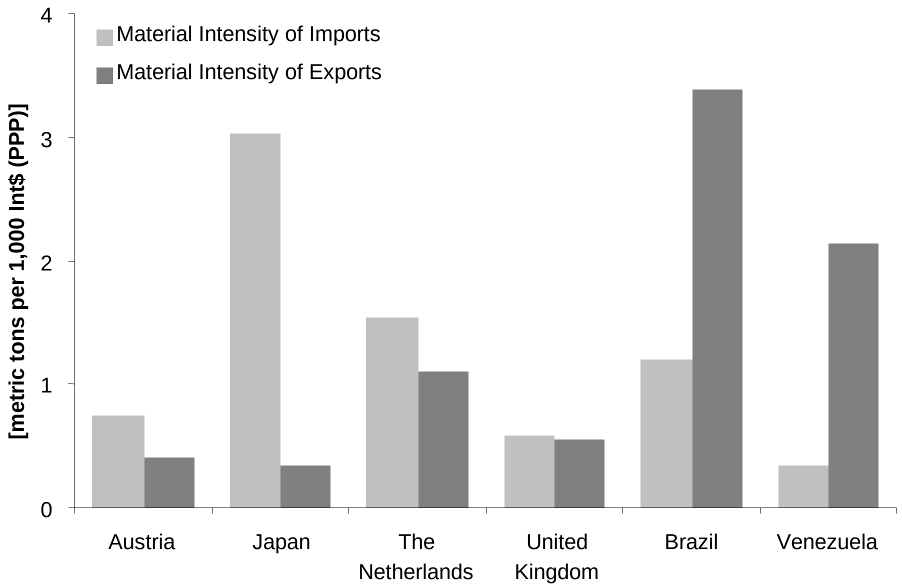



Figure 9: **Material Intensity of imports and exports in industrial countries, Brazil and Venezuela (1995)**

Sources: Matthews et al. 2000, Schandl and Schulz 2001, Authors of Matthews et al. 2000 (pers. comm.), Amazonia21 (case studies), World Bank

# 3 APPLYING LOCAL MATERIAL FLOW ANALYSIS IN THREE AMAZONIAN COMMUNITIES[11]

## 3.1 OVERVIEW

During implementation of Amazonia21, especially during the project workshops in July 1999 (Minihof) and January 2000 (Leticia), it was agreed to carry out Local Material Flow Analysis (LMFA) studies in 3 of the 4 countries surveyed by the project. According to specific interests and *foci*, locations and characteristics of the groups under consideration varied. CIMAR of Bolivia selected a district of pioneer settlements (Santa Rosa) in the forests of Bolivian Amazonia; NAEA of Brazil selected 3 communities located in a national park on Marajo island in the Amazon delta; and IMANI of Colombia focused on the municipality of Puerto Nariño located by one of the tributaries to the Amazon.

The LMFA concept and methodology was presented at the »Train the Trainers« workshop in Minihof. It was then agreed that the researchers would locate the researched society and gather preliminary information up until the workshop in Leticia. After further discussion there, the locations were finalized and the data-gathering phase stretched over most of 2000, with an additional opportunity for discussions (mainly with Simron J. Singh of IFF) at the September 2000 workshop in Vienna. During the entire study phase, there was the possibility of contacting IFF advisors via e-mail; the partners, however, made only intermittent use of this channel. The current report is based on these discussions and on material received during June/July 2001 in preparation for the final project report. An additional source of material included here is the presentation by Armin Mathis on »Socio-Ecological Transition in the Amazon: a case study in the communities of Pedreira, Caxiuanã e Laranjal« at the 4S/ISSR Conference »World in Transition« held in Vienna, Austria (Sept. 2000). The paper was presented during a session entitled »Society and Nature in Transition. Cultural and physical dimensions of societal change«, which was organised by IFF and brought together the case study in Amazonia with another case study in India, together with a conceptual presentation prepared by IFF.

Researchers in three countries collected data, the amount and type of which exceeds the necessity of performing a LMFA. Apart from relevant material flows, which all studies illustrate, researchers investigated land use information, cultural descriptions, socio-economic data, and environmental issues. However, none of this was done in a standardized way, so that the information amassed might be interesting in itself but does not allow for in-depth comparison.

## 3.2 RESULTS

This section attempts to give a generic overview of the data available in the reports of partner institutions engaged in LMFA studies. In addition, remarks on the data quality are made and missing components identified. The next section then takes up certain parts of the data and compares them as far as possible. General conclusions are drawn for these comparisons and themes for further research suggested.

Rather than calculating full LMFA balances for the respective communities observed, the studies mostly focused on important *input* and *stocks* categories. This is partly due to availability of data but also due to importance, since input data gives a first idea on the material consumption of a society and portrays the status and level of economic integration with national or world markets. All three studies present data on food consumption; there are

[11] This chapter was written by Clemens M. Grünbühel of IFF – Social Ecology

reliable figures for agricultural production; fossil fuels consumed in the households have been accounted for; and there is fair data for the amount of biomass extracted from the domestic environment. In accounting for material stocks in the societies considered, the studies give much detail on materials used in the homes of the inhabitants, and imported consumer goods are listed, at least by the item if not in terms of weight. As for output flows, some data is given on the discharge of solid waste and most important export flows, particularly biomass exports originating from agricultural production and domestic extraction (fish and timber).

Shortcomings, in order to arrive at a LMFA balance, can be identified on the input side in the lack of import data on finished products (material compounds); likewise, feed for livestock has not been estimated realistically; and – depending on where the economic gravity of the studied economy was located – either agricultural production or domestic extraction from hunting and gathering seem underrepresented. Regarding stocks, despite accounting for private buildings, communal material stocks were omitted[12] and livestock and human weight not included[13]. Outputs were partly accounted for as exported material as well as waste (to land), however emissions to air[14] and to water have not been considered (and thus, no balancing is possible). Also, deliberate disposals (dissipative losses, which are rather important in, e.g., farming communities) have not been regarded[15].

Although kept separately in MFA balances, water consumption can be an important indicator on the economic structure of the society. All studies attempted to measure household consumption of water, however, water expenditure in agriculture (irrigation) is not given. A full accounting of water use would, however, be interesting, especially in comparison between the three cases, being geographically and culturally diverse.

Overall, although they do not present full LMFAs, the studies nevertheless can be considered as relevant case studies on biophysical and economic developments in the globally important region of Amazonia. With relatively little additional effort, the studies could be organised and presented in such a way that they are suitable for international publication and international comparison with other studies past or on-going in the MFA community.

### LMFA Bolivia

The researchers of CIMAR carried out a study in the Municipality of Santa Rosa del Sara and with the cooperation of the Association of Small-scale Farmers in El Chore. 8 farming families from 4 communities in El Chore canton were selected and data generation took place among these. For the study, these 8 families (58 persons) were treated as one community. According to the author of the study (Irma Lizarazú Palacios of CIMAR) this is possible, because the settlers in the area are socially and culturally homogenous, most persons being occupied in subsistence agriculture. The area has been described as being under cultivation since relatively recent times (mid 1960s). The pioneer settlers originally arrived from the Bolivian highlands and now practice short-fallow shifting cultivation, together with some livestock herding and maintenance of permanent orchards. The society is mostly self-subsistent, only very little surplus is produced and exported.

The study comprises many interesting material and economic aspects of the ‘society’ (i.e., the 8 families investigated). It provides detailed information on agricultural and livestock production and gives an idea on the characteristics of local consumption and interactions with external markets (see CIMARs LMFA report for Amazonia21 [CIMAR 2001]).

In order to achieve a full MFA balance, several sets of data need completion or rearrangement. On the *input* side, while agricultural production (*harvest*) shows complete

[12] Although the Colombian study accounts for concrete pathways.

[13] Population sizes, however, are given.

[14] It would have been interesting to determine $CO_2$ outputs.

[15] The Brazilian study is an exception here.

data, imports have not been completely covered and food intake by humans shows figures in kcal, but not in kg. Oxygen for respiration and used in combustion processes should also be taken into the account.

The *societies stocks* have largely been covered by calculating for materials contained in buildings and structures. However, tools and machines, which are given as account of items, could be converted into mass units and added to the account of stocks. In addition, total weight of humans and livestock form part of the stocks.

For *outputs*, we find data on exports and scattered information on several forms of waste. Waste and emissions are left out of the output account as categories. Also, there must be a clear distinction of what is considered as waste and what is unused extraction (‘loss’). Waste is usually defined as material that has been processed and consumed by the society, while unused extraction never enters a processing cycle, and thus does not form part of the MFA balance. Losses of material during processing should be considered as waste, and therefore as outputs.

Some data sets cannot be understood if the applied method is not explicated. There is little indication of the methods used and the uncertainties corresponding to these methods.

Units and conversion factors are often omitted, but nevertheless necessary in order to make clear the figures represented in the different tables.

The researchers gathered initial data for establishing an Energy Flow Analysis (EFA). It is possible to account for energy flows, yet this should be planned in a separate effort. Necessities for accounting energy flows include the converting all energy-laden materials into calorific values, defining the use and agent of energy conversion for all flows, and considering exports of energy to other societies. A full MFA account definitely serves as the required basis for such conversions.

Land use and time use data is also presented. Although not part of Task 2, this data is definitely related to the issues dealt with in the project and serve as important additional information. Using the material presented, an account for HANPP (*Human Appropriation of Net Primary Production*) and further time use analysis could be achieved if so desired.

**LMFA Columbia**

Very intensive data research has been carried out under the framework of Amazonia21 in Puerto Nariño. German Ochoa carried out the research under the supervision of Allan Wood of IMANI. Apart from a good wealth of MFA data, there should be enough data to carry out an Energy Flow Analysis and Land Use analysis of the municipality. Additionally, the analyses of the fishing and timber extraction sectors in the municipality give a great wealth of background information on the economic characteristics of the locale (see reports for task 3 of Amazonia21 [Botia et al. 2001]). Further, if the data is assembled in a structured way, it can easily be related to current socio-economic transition and cultural change on-going in the area. Also an interesting attempt to record time-use data has been made, which, if provided with the methodological framework could give interesting insights on the labor characteristics of the studies society (e.g. subsistence vs. paid labor; efficiency of various work tasks and economic efforts, etc.)

Extraction and import of biomass used for human and livestock *food consumption* seems to be complete. This data could be counter-checked with agricultural harvest and fish extraction data. Using the food consumption tables it would be possible to estimate the biomass extraction relating to hunting and gathering activities in Puerto Nariño.

There is good data on the *extraction of fish and timber* (domestic extraction of biomass). As said in the above paragraph, this could be compared to food consumption but also with energy consumption related to cooking, which should equal the amount consumed if subtracted by export figures.

Domestic extraction originating in agriculture seems complete. However, biomass extraction due to *hunting and gathering* activities are lacking[16]. Also, data on livestock *grazing/scavenging/foraging* would also be desirable (but can be retrieved from existing scientific literature).

Except for material used in building construction and agricultural harvest, where all materials are accounted for in detail, there is no indication of any other extraction of *biomass* (e.g., wood for fencing, for tools) or *minerals* (stones, sand) from the domestic environment.

Household consumption data for *fossil fuels* is complete. What is lacking, is consumption of fossil fuels outside private homes, e.g. for generators, vehicles, etc.

Most long-lived *products* (i.e. material compounds) in the households are listed, albeit not mentioning average weights of different products. For the sample households, there are no estimations on total weight of furniture, household utensils, and clothes (to be added to stocks). Also, consumable goods (classified as imports, not as stocks), such as soap, matches, industrially processed food, etc. have not been accounted for.

Household *water* has been accounted for. Irrigation water for fields and gardens, equally constitute a large flow in traditional societies and therefore should also be assessed.

Although figures for *timber exports* out of the municipality cannot be found in the timber study, these export figures are certainly available and should be included in the account. Also, *products* leaving Puerto Nariño as exports (e.g. handicrafts) should be listed.

In order to assess the growth rate of stocks, *material inputs* that are not immediately consumed but rather remain in the society (in order to arrive at the NAS indicator) must be included. Otherwise, the account of society's stocks seems complete.

**LMFA Brazil**

The study performed on the island of Marajo surveys the 3 communities Pedreira, Caxiuanã, and Laranjal. These are relatively recent in origin and are indigenous communities lying within the limits of a nature conservation area and a nearby scientific research station. The communities were studied in-depth and over a long time period by a researcher (Karina Ninni Ramos, with supervision by Armin Mathis of NAEA), so we conclude that the data is very reliable. The material flow balance is almost complete with only a few clarifications and minor data additions to be made. Apart from material flows, there are attempts to assess the status of the monetary economy and population structure of the three communities.

While the study presents a complete account of materials flowing into the society, accounting of society's material stocks and export flows is incomplete. *Stock accounting* is lacking, although the values could be easily obtained, since there is data on housing and building construction as well as possession of durable goods in the individual households. Equally, net addition to stocks (NAS) should be possible to account for. As for *outputs*, until now, there are no figures, although – in light of the ample knowledge about the communities investigated – exports could easily be determined (minerals from the stone quarry, agricultural products, and other products (handicrafts, etc.) exported from the communities). Also, $CO_2$ outputs are obtainable knowing the population sizes of livestock and humans, as well as the amount of fossil fuels being combusted.

There has been an attempt by the Brazilian authors to include an account of »hidden« flows into the LMFA, i.e. an estimate of materials moved by the society, albeit never actually entering the society's economy, i.e. never given any value. Especially when confronted with large overburden mass, as found in mining of minerals, such an attempt is understandable. However, there are several points to consider here. Firstly, the account of »hidden« materials has to be kept separate from the LMFA balance, since balancing is not possible with flows that neither »enter« nor »leave« a social boundary (i.e. the economic system of the society).

[16] With the exception of fish extraction.

Secondly, the material moved is not really extracted from the domestic environment, since it is merely re-located and remains un-processed. Thirdly, among some more reasons[17], problems of a clear-cut accounting arises, both regarding the methodology used for determining amounts of »hidden« flows, as well as with the conceptual logic, since these flows do not enter the socio-economic system and leave it after processing.

## 3.3 COMPARISONS

The following comparisons of selected results provide an outline for possible conclusions to be drawn from the Local Material Flow Analyses (LMFAs) conducted under task 2 in the Amazonia21 research project on strategies for sustainable development in the Amazon basin. To be sure, the ideas presented must be seen as preliminary, since data is not yet fully conclusive, the analysis for each case is sketchy, and the methods of data acquisition not always comparable. However, some tendencies can be observed and certain lessons drawn amidst the heterogeneity of data. The following paragraphs single out certain aspects of material flows and resource use in the respective cases and try to compare them. I do not attempt to compare full LMFA balances, since these have not yet been completed in any of the cases. Interspersed are some observations that provide some additional information about the sites and their populations, which I relay from reading the reports and being in contact (in person or through electronic communication) with the researchers or their supervisors involved in the three LMFAs of Amazonia21.

One measure to assess the degree of subsistence of a particular society is to look at the origin of its nutrition. Usually, a society is defined self-subsistent when the major part of its food origins from its own production, i.e. from its fields, forests, waters and other natural resources, which can be termed as elements of the *domestic environment*. Admittedly, this definition is kept vague and qualitative rather than establishing a fixed threshold because situative variation and special redistributative arrangements or economic specialization can make a closer assessment of the society necessary. In the present case studies, however, I believe that the above definition of self-subsistence suffices, as we shall see below.

Agricultural production and food consumption are, hence, a particularly important issue in this regard. With the data at hand we are able to see, whether or not a community is able to provide for its nutritional requirements and whether, how much, and what kinds of foods need to be imported, through commerce or otherwise, in order to satisfy at least its basic metabolic needs. Many sustainability issues already appear on this level of analysis, since self-sufficiency depends on a variety of factors ranging from population size, economic options, natural resource availability, and culture.

The first of the 3 case studies concerns 4 communities in the district of El Chore, Municipality of Santa Rosa, Bolivia. The 4 settlements located in Bolivia's share of the Amazon basin are the product of pioneer settlement of farmers descending from the highlands. Beginning in the late 1960s there appears to have been several migrative waves and corresponding influx of people. They mainly practice swidden farming together with some livestock breeding. Their main agricultural products are rice, maize and yucca and meat of sheep, cattle and pigs.

Having been established only recently, it would not come as a surprise if the settlements did not show full adaptation to the local ecosystem and did not self-consciously rely on traditional forms of subsistence agriculture. In fact, it seems as though the communities are struggling to make ends meet and to produce enough for their livelihood. Certainly not ideal conditions for formerly highland dwellers, the tropical fauna and flora seem to hamper the economic

[17] There is a long-standing debate on how to treat »hidden« flows (»unused extraction«) within the MFA community. For national-level studies this has now resulted in a standard as reflected in the recent EUROSTAT guide ('Economy-wide Material Flow Accounts and derived Indicators – A Methodological Guide', Office for Official Publication of the European Communities, Luxembourg, March 2001). For local MFAs this is an issue yet to be resolved.

aspirations of the settlers. 15% of the potential agricultural harvest is therefore lost in the production process. Unfortunately, it is not known what the exact causes of these losses are but the loss rate seems to be in agreement with many tropical swidden-farming societies that have been reverting to this practice only relatively recently[18]. Non-traditional swiddening, especially if coupled with a high population density and, therefore, land area constraints, are prone to weed and pest problems (Kellman and Tackaberry 1997).

In observing the purpose of crops planted in the area, results show that 72% of the agricultural production is sold on the markets in the municipality. Although the type of crops produced do not necessarily indicate cash crop agriculture, this figure suggests a high level of integration into the wider economy of rural Amazonian Bolivia. Only 13% of the agricultural production is self-consumed. When looking at the ratio between imported and self-produced food consumed in El Chore, 41% of food is imported versus 59% domestically extracted. The latter includes not only agricultural production, but also meat from livestock and wild catch, while imports refer to food purchased on local markets[19].

A similar case appears to be presented in Puerto Nariño, Columbia, an administrative settlement with a considerable fishing and logging industry and inhabited primarily by indigenous Ticuna. Here also, the community seems to be fairly well integrated into the mechanisms of the local markets (with the nearby administrative capital of Leticia as a focus point). 52% of food consumed is produced by the community's population, whereas 48% of foods are purchased and thus imported to the community. The average of food consumed per inhabitant, however, ranges from approx. 1kg to 3kg per day, which is an indication of the range of economic integration among the inhabitants of Puerto Nariño. It seems merely a portion of the community's inhabitants is economically well-integrated, while a significant part of the indigenous people continue practicing traditional modes of production, such as small-scale agriculture and hunting and gathering (incl. fishing). They have, however, the opportunity to sell their surpluses, if available, to the local markets, which are demand-driven by relatively isolated Leticia. When looking at the economically and environmentally particularly sensitive sector of fish extraction, we find that more than one fifth of the fish extracted from the waters surrounding Puerto Nariño is exported, while the rest is self-consumed[20].

An entirely different picture is presented by the Brazilian case. Located on the Island of Marajó in the delta of the Amazon river, the three settlements studied are very much indigenous communities without a distinct administrative or economic designation. The three communities, Pedreira, Caxiuanã and Laranjal, are located within an area marked as a natural reserve and are thus relatively unattached to modern economic systems. The local economy is characterized by hunting and gathering (mainly fish) and small-scale agriculture (mainly manioc) for self-consumption. Only recently has there been some handicraft production for trade with tourists and production of rocks from a local quarry, which are sold to foreign merchants. 208,5 kg/cap.a of food are produced for self-consumption compared to 72 kg/cap.a which are imported through local merchants. Domestic extraction includes fish catch (107,3 kg/cap.a), manioc (67,4) and produce from hunting and gathering activities on

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[18] In response to changing socio-ecological and economic conditions, many societies revert to swidden farming in case of need for new land, at least for the initial period, and after several years revert back to permanent agriculture. This occurs even with farmers with a long-lasting tradition of permanent farming and a high level of, e.g., irrigation systems or agricultural technology. Reverting to swiddens often seems to be a coping mechanism in extreme or crisis situations, a practice with which – though to the expense of high human labor input – food can be brought to the table without additional inputs and infrastructure. (see Hanks 1972, Kellman and Tackaberry 1997)

[19] The domestic consumption data does not include milk and eggs produced locally. Thus, this figure can be expected to rise slightly though arguably not to the extent indicated in the CIMAR report.

[20] Fish exported: 22t/a, fish self-consumed: 94,5t/a; according to the authors of the Amazonia21 report „The Fishing Sector in the Trapecio Amazonico and in Puerto Narino (Colombia)", the export figures for fish are likely to be higher since not all fish extracted from Puerto Narino's waters bypasses the town before being sent to Leticia, the areas commercial hub.

land (33,8). Compared with the other cases, the three Brazilian communities' diet consists of 74% domestic production and 26% imported foodstuffs.

| | Relation imported food to self-produced food | Percentage of produce destined for export | Exported produce |
|---|---|---|---|
| El Chore | 1 : 1,4 | 72% | agricultural products |
| Puerto Nariño | 1 : 1,08 | 19% | wild fish catch |
| Marajo | 1 : 2,8 | - | not yet available |

*Table 1:* ***Degree of subsistence and exported produce from agriculture and hunting and gathering in three Amazonian communities.***

The degree of attachment to the modern economy is also visible when observing the consumption of material resources for housing and infrastructure (*society's stocks*). Traditionally the most important building material in the entire Amazon basin has been wood. This is still the case in the Brazilian communities studied, who dwell in traditional wooden establishments and use footpaths and waterways for transportation. 4,06 tons or 0,0203 t/cap of wood is used to provide adequate housing for its inhabitants. By comparison, the newly established communities in Amazonian Bolivia cannot rely on such lightweight materials and use a total of 167 tons or 2,9 t/cap of building material resources. The materials include wood as well as clay and the indigenous *tacuara*. Probably even more material, although there is no data at hand, is consumed by the Colombian community of Puerto Nariño. For buildings and pathways, they use cement, sand, gravel, brick, and wood. The cement alone lists at 250 tons (0,148 t/cap).

Although we are not yet confronted with complete data, the analysis of consumed energy carriers in the three case studies confirms what we have suspected after looking at other crucial sectors of material consumption. The preliminary analysis of energy consumed in the three sites unveils vast differences, both in kind of energy carriers applied as well as total amount of energy consumed.

| [per capita figures] | Gasoline | Cooking Gas | Firewood |
|---|---|---|---|
| El Chore | 19,2 l/cap.a | 2,9 kg/cap.a | 31,5 kg/cap.a |
| Puerto Nariño | 292,3 l/cap.a | 3,8 kg/cap.a | -- |
| Marajo | -- | 0,1 kg/cap.a | 3 kg/cap.a |

*Table 2:* ***Energy sources consumed in three Amazonian communities***

While in El Chore a certain amount of gasoline is needed to transport agricultural produce to the nearest markets and possibly in order to power selected agricultural machinery, gasoline consumption rises highly in Puerto Nariño due to motorized boat transport and generators supplying electricity for the entire town. Bottled gas, used for preparing meals at home, seems to be widespread in the Amazon basin, however, amounts consumed vary widely in as well as among the three sites. To a certain extent, gas has replaced firewood for cooking in all locations. Unfortunately, we do not have data for the Colombian case, but the Bolivian and Brazilian studies suggest that there are different requirements for cooking energy. When observed in added amounts of energy units, we are confronted with a Brazilian indigenous community (Marajó) that consumes 25 times less energy for cooking and transportation than the young pioneer settlers of El Chore, Bolivia and 197 times less energy than the much larger administrative town of Puerto Nariño in Colombian Amazonia.

| [MJ] | Gasoline | Cooking Gas | Firewood | Total | **Total/cap** |
|---|---|---|---|---|---|
| El Chore | 36998 | 8089 | 28288 | 73375 | **1265** |
| Puerto Nariño | 16326697 | 309267 | -- | 16635964 | **9873** |
| Marajo | -- | 674 | 9254 | 9928 | **50** |

*Table 3:* ***Energy conversions of fuels used in three Amazonian communities***

### 3.4 PRELIMINARY CONCLUSIONS

The three studies describe the material basis of – albeit culturally very different – non-industrial societies in Amazonia. These are undergoing transition due to outside influences and a willingness to link up to their outside worlds. All three societies show different obstacles in their thriving for economic development. While the inhabitants of Puerto Nariño unwillingly deplete their own natural resources (e.g. fish stocks), the people of Santa Rosa must exert pressure on their land resources. This seems due to the necessity of producing for the market and, at the same time, relying on domestic resources to maintain subsistence. We are confronted here with typical extractive economies, exporting natural resources out of the society virtually unprocessed, while there is an increasing pressure, through both economic and social channels, that forces consumers to obtain industrial products from traders and merchants. In Marajo, we are confronted with a different set of factors of transition. The structure of the national park and the scientific base, puts the inhabitants of the three investigated communities under externally conceived development schemes, which, on one hand, brings commodities like solar lighting, but on the other hand, forces the people to abide by the rules laid out for the national park. Here also, the impact of economic development leads to social transition and there is no prospect of the inhabitants remaining »traditional«, whether they want that or not.

As for balancing the Local Material Flow Analysis, we suggest to generate the standard MFA indicators, which is roughly possible if above mentioned data gaps are filled (see *Results*, above).

- Domestic Extraction (DE): Resources extracted from the Domestic Environment
- Domestic Material Input (DMI): DE + Imports
- Domestic Material Consumption (DMC): DE + Imports - Exports
- Total Society's Stocks (TSS): Absolute amount of permanently stocked material
- Net Addition to Stocks (NAS): Increase of permanently stocked material per year.
- Domestic Processed Output (DPO): Exports and waste

This will allow for standard comparisons among the three case studies and an assessment as to where the society lies on the gradient of economic integration with the national economy. We can then assess the material requirements for such transitive communities in the Amazon region and correlate these with the results of the national MFAs available. The results are definitely of a quality[21] that deserves an international publication comparing the studies and drawing conclusions for Amazonia, however some effort should go into completing the balances. With the additional material available on social and cultural

[21] Though not all three studies to the same degree.

characteristics (Puerto Nariño), economics (Puerto Nariño, Marajo), and history (Santa Rosa), the LMFA data could serve as an point of departure for further analysis with the prospect of developing individual studies and publications.

Several themes are worth expanding on and should be subject of further research. In brief, I attempt to point out a few issues deriving from the comparative data presented above.

- The degree of integration into the modern world economy varies enormously within the Amazon basin. The specific location, the distance to commercial hubs, the politico-administrative function of the settlement, and its respective economic and political history seem to determine the degree of integration to a much wider extent than the fact that the communities share the same wider ecotope.

- As could be expected, traditional communities can be termed as more environmentally sustainable, since they consume less resources and materials. However, this must be weighed against factors, such as whether basic needs are met and the status of the quality of life in these settlements. We also must look at the term »traditional« and whether it means more than lack of access to resources. The Brazilian case presents a community that is, by the legislation of a natural reserve, prevented from expanding economic integration and development. Here we need clear-cut definitions for *sustainable development* and strategies on how it can be achieved.

- All communities, though culturally, historically and geographically unrelated, share common economic strategies for establishing their livelihoods in precarious ecological conditions. They engage in multiple activities of resource extraction, thereby distributing risk and securing the subsistence minimum. Swidden and small-scale permanent agriculture as well as hunting and gathering and fishing are evident. In addition we find small-scale production of handicrafts and extraction of primary resources, such as wood and rock.

- Although the societies, which are the concern of the case studies presented here, are all part of the wider area termed »Amazonia«, i.e. the greater watershed of the Amazon river, the cases are obviously very diverse and have varying backdrops of regional as well as national socio-economic integration. Perhaps these studies can also serve as an illustration of the range of socio-economic types we are dealing with when talking about »sustainability in Amazonia«. Every type of society produces its specific sustainability issues, which all have to be tackled, if one is serious on the entire issue. In this respect, MFA on the local level (LMFA) can serve as a tool, with which one can relatively rapidly figure the dominant socio-economic structure of a society and its attached sustainability issues, without having to delve into a culture in the way anthropologists usually do, i.e. spending years with a particular society and studying its people in great depth and arguably with meticulous detail.

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