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A multi-purpose grammar generating a multi-scale integrated analysis of Laos

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ABSTRACT

In this study we propose an application of the MuSIASEM approach which is used to provide an integrated analysis of Laos across different scales. With the term “integrated analysis across scales” we mean the generation of a series of packages of quantitative indicators, characterizing the performance of the socioeconomic activities performed in Laos when considering: (i) different hierarchical levels of organization (farming systems described at the level of household, rural villages, regions of Laos, the whole country level); and (ii) different dimensions of analysis (economic dimension, social dimension, ecological dimension, technical dimension). What is relevant in this application is that the information carried out by these different packages of indicators is integrated in a system of accounting which establishes interlinkages across these indicators. This is a essential feature to study sustainability trade-offs and to build more robust scenarios of possible changes.

The multi-scale integrated representation presented in this study is based on secondary data (gathered in a three year EU project – SEAtrans and integrated by other available statistical sources) and it is integrated in GIS, when dealing with the spatial representation of Laos. However, even if we use data referring to Laos, the goal of this study is not that of providing useful information about a practical policy issue of Laos, but rather, to illustrate the possibility of using a multipurpose grammar to produce an integrated set of sustainability indicators at three different levels: (i) local; (ii) meso; (iii) macro level. The technical issue addressed is the simultaneous adoption of two multi-level matrices – one referring to a characterization of human activity over a set of different categories, and another referring to a characterization of land uses over the same set of categories. In this way, it becomes possible to explain the characteristics of Laos (an integrated set of indicators defining the performance of the whole country) in relation to the characteristics of the rural Laos and urban Laos. The characteristics of rural Laos, can be explained using the characteristics of three regions defined within Laos (Northern Laos, Central Laos and Southern Laos), which in turn can be defined (using an analogous package of indicators), starting from the characteristics of three main typologies of farming systems found in the regions.

Keywords: rural system, multi-scale analysis, integrated analysis, sustainability, Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM), spatial analysis, Geographic Information Systems (GIS), sustainability indicators, farming system, societal metabolism

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Part 1 The Theoretical Challenge

1.1. The integrated characterization of the metabolic pattern of rural systems

In this case study we provide an integrated characterization of the "metabolic pattern" of Laos across different scales. With the term "metabolic pattern" we mean a quantitative analysis of the density (per hectare) and intensity (per hour of human activity) of flows (food, money, energy, nutrients, water) which are relevant for the reproduction of the Laotian system considered at different hierarchical levels of organization – e.g. a household, a village, a region, the whole country. The chosen approach presented here to generate the quantitative analysis results is an application of the fund-flow model of bio-economics proposed by Georgescu-Roegen, which is implemented using the MuSIASEM approach. The integrated mapping of flows is obtained by defining typical benchmark values for the various considered flows – e.g. kg/hour & kg/ha; MJ/hour & MJ/ha; $/hour, $/ha; liters/hour & liters/ha – referring to different elements of the system, described using two different types of funds:
(a) a multilevel matrix of compartments of human activity (when considering these flows against the FUND human activity); and (b) a multilevel matrix of compartments of land uses (when considering these flows against the FUND colonized land).

After having generated this integrated representation across levels and dimensions it becomes possible to generate different packages of quantitative indicators, which characterize the performance of the metabolic pattern of Laos in relation to:
(i) different hierarchical levels of organization (when the metabolic pattern of farming system is represented at the level of households, rural villages, different geographic regions of rural Laos, the whole country); and (ii) different dimensions of analysis (when considering indicators of performance referring either to the economic performance, or social impact, or technological performance, or ecological impact).

This application has an important innovative aspect: even though the different packages of indicators generated in this way do reflect the non-equivalent perceptions generated by the adoption of different scales and different dimensions of analysis [e.g. economic performance at the level of the house, social performance at the level of the whole country, ecological impact at the level of a region], the MuSIASEM approach provides an integrated meta-system of accounting capable of establishing interlinkages across the changes taking place over the various indicators. This feature is essential to study sustainability trade-offs and to build more robust scenarios of possible changes.

Finally, we want to flag to the reader that the multi-scale integrated analysis presented in this study is based on secondary data (gathered during a three year EU INCODEF project in the 5th FP) – SEAtrans – which ended in 2005), which have been integrated using other available statistical sources, when needed. The use of this secondary data has the only goal to illustrate the usefulness of the multipurpose grammar developed to produce an integrated set of sustainability indicators at three different levels: (i) local; (ii) meso; (iii) macro level; using a multi-level matrix of categories for both Human Activity and Land Use. Therefore, it should be clear that this study is an attempt to explore new applications of the MuSIAEM method in theoretical terms and not that of providing useful information about how to solve a specific sustainability problem of Laos. In particular, the most important result of this study is to indicate the possibility of using simultaneously two multi-level matrices – one referring to a characterization of Human Activity over different categories; the second referring to a characterization of Land Use over the same set of categories - for a multi-level integrated analysis of the metabolic pattern of a country.

When dealing with the process of self-organization of societies, one has to adopt non-equivalent definition of “the size of the observed system”, which are all relevant. For example, the size of a household, a village, a province, or the whole society can be expressed using different proxy variables: population (number of people), Gross Domestic Product (in US$ of a reference year); Total Energy Consumption (e.g. Tons of Oil Equivalent); total hectares of land (size in terms of space occupied); total tons of water consumption (water footprint). For this reason, when using numerical indicators of sustainability, analysts tend to use ratios among these non-equivalent definitions of size: population density (people over space), GDP per capita (money over people), energy consumption per capita (energy over people), energy intensity (energy over money), water consumption per hectare of land use (water over space). However, these ratios – which are providing crucial information and therefore should be considered key indicators – can only be defined at a given hierarchical level. This is why they result incoherent, when used for a characterization across hierarchical levels. For example, the population density of Canada (the whole) is different from the population density of the State of Ontario (a part of Canada) and different from the population density of the city of Toronto (a part of Ontario). In the same way, the energy consumption per hour in Spain – average for the whole country – is different from the energy consumption per hour in the manufacturing sector of Spain (an economic compartment), which is different from the energy consumption per hour of a given manufacturing plant. In order to be able to study the effects of specific changes in special compartments, or the effects of structural changes in socio-economic systems, it is essential to learn how to establish a relation between changes in the value of indicators which are referring to parts and to the whole.

In particular, in this case study of Laos we deal with two crucial non-equivalent semantic definitions of the size of a “farming system typology”: (A) the size expressed in terms of hours of Human Activity (the activity of a number of people in a year), and (B) the size expressed in hectares of Colonized Land (the amount of land which is used and which is affected by that human activity in relation to the different tasks carried out by humans). These two non-equivalent definitions of a size of the “farming system typology” obviously refer to the same observed system (a farming system), which can be observed at different hierarchical levels and scales: at the level of a household, a village, a geographic region in Laos, or the whole country.

We believe that it is important to focus on this issue, since the epistemological challenge of how to bridge quantitative representations defined across different dimensions, hierarchical levels and scales seems to be basically ignored by those working in the field of sustainability analysis. On the other hand, socio-economic analysis generally express the size of the observed system either in “people” or “GDP” (two non-equivalent mappings of size, which can be linked by using the variable GDP per capita), but the resulting numerical value refers to the chosen level of analysis (either a part or the whole) and it does not say anything about the characteristics of the system, when considered at different levels (either the whole or other parts).

1.2. Using an integrated set of indicators to study sustainability

The analysis of sustainability of farming systems is an important field of application for sustainability analysis, since it must adopt a quantification based on “Land Use analysis”, because farming, by definition, is about land uses. Therefore, when dealing with farming system analysis it is unavoidable to find a direct relation between the set of categories of Human Activity associated with agriculture (the various tasks performed in the farm over the year) and a resulting set of categories of Land Use associated with the resulting agricultural practices (the various land uses established over the year because of the tasks allocated in farming).

Dealing with the integrated characterization of the performance of a farming system is particularly challenging since the information space which that has to be generated by the analyst to produce an integrated package of relevant indicators is especially complex. This problem has been addressed in previous works where the MuSIASEM approach has been applied to generate a multi-scale integrated characterization of the performance of farming systems (Giampietro and Pastore 1999, Pastore et al. 1999, Gomiero and Giampietro, 2001; Giampietro 2003).

To make a long story short, we provide below a few examples of the results obtained in these previous applications of the MuSIASEM approach to farming system analysis. The material presented in this introductory section (the results of previous applications of MuSIASEM) has been generated within the activities of an EU project in rural China. These results are briefly exposed here to better frame the goals of the Laos case study. A more detailed discussion the results briefly mentioned below is available in a special issue of Critical Review in Plants Science – Paoletti et al. (guest editors), 1999.

Let's start this quick overview by introducing the concept of an integrated package of indicators. An example of a multi-objective integrated characterization of the performance of different elements of the same farming systems (from Giampietro, 2003) is given in Figure 1. The radar diagram shown in this figure - nowadays very popular in sustainability analysis - represents the set of indicators of performance, which are chosen to characterize the performance of the elements considered in relation to different criteria and different targets.

Typologies of household on a Multi-Criteria performance space

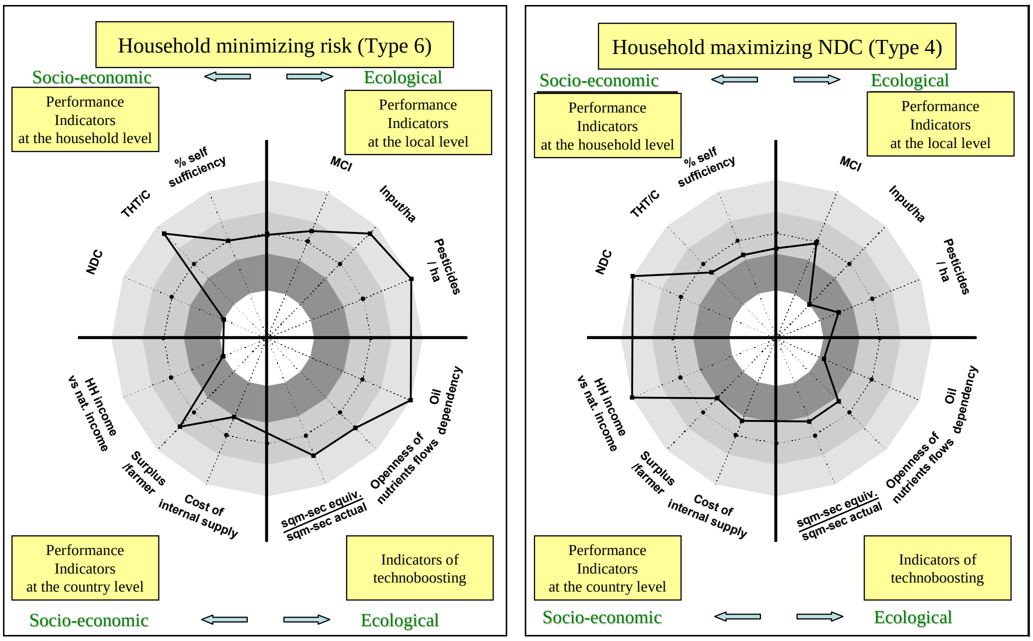

Figure 1: Multicriteria Space used to define the performance of a farming system

In the previous example of analysis we are dealing with the characterization of two different household types operating within the same farming system. The socio-economic indicators are on the left side, whereas indicators referring to ecological impact are on the right. The same system of characterization can be applied, within the same typology of characterization, to a different level, for instance to the level of a rural village made up of households belonging to a given set of household types.

The same characterization used in Figure 1 to represent different households is used in Figure 2 to characterize a village. What is important in this case, is that we can use such a characterization in two ways: (i) to characterize a real village, when using data gathered at the level of the village (this would be the graph on the right of Figure 2); and (ii) to characterize a virtual village (a typology of village) which can be defined as generated by a population of household distributed over a known profile of household types [e.g. a village made up of a population from households belonging to 6 typologies, with a given distribution of households over these 6 types].

"Typologies of rural village reflecting a different mix of household types" AND
"Actual characteristics of a rural village using the same Multi-criteria space"

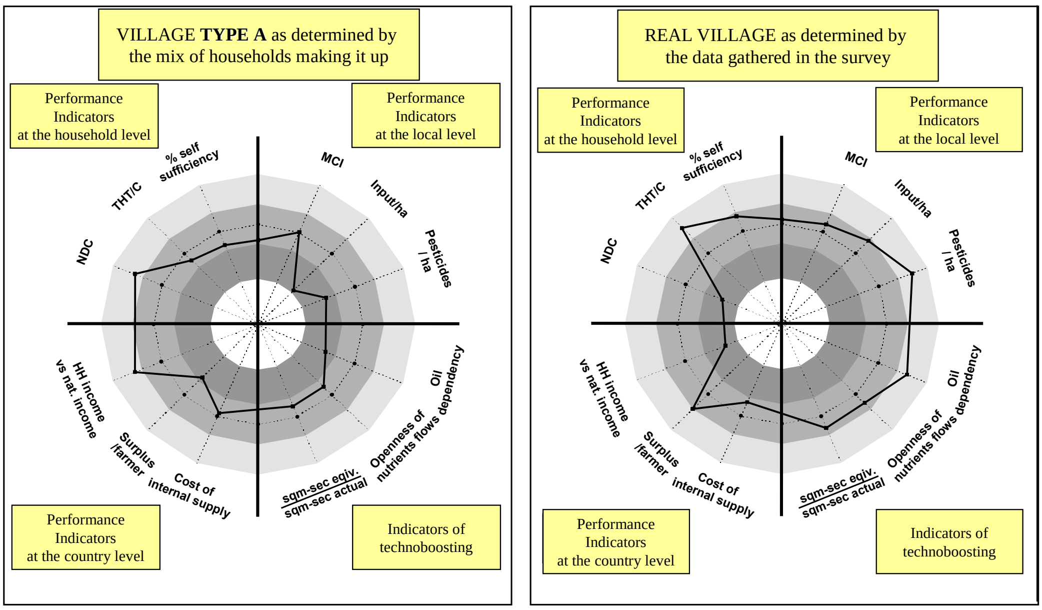

Figure 2: Multicriteria Space used to define the performance of a farming system

Please note that the set of indicators used to characterize the performance of either a household or a village are the same (they refer to the same farming system typology – the same metabolic pattern). In conclusion, what presented in Figures 1 and 2 is an integrated set of indicators, which is used to characterize the performance of a farming system at different hierarchical levels – a household and a village – using the same multi-objective integrated representation. The two elements – the household and the village – can be seen at this level as one part and the whole, determining the expression of the metabolic pattern of this farming system, and they have different size (the village is made up of households).

The different criteria of performance used to organize the various indicators over the radar diagram, based on the use of two axes of symmetry, are indicated in Figure 3.

– ***the left side of the radar diagram*** deals with indicators referring to the socio-economic dimensions;

– ***the right side of the diagram*** deals with indicators referring to the ecological dimension;
– ***the upper side of the radar diagram*** deals with indicators referring to the local scale (either the household or the village level);
– ***the lower side of the radar diagram*** deals with indicators referring to a larger scale (the context within which the element considered is operating).

This representation is based on the flag-model, what is a system of benchmarking indicating the level of performance indicated by the value taken by each indicator, by assigning different colours to different ranges of values taken by the various indicators. In particular, in this example, the areas are described as green = good performance; yellow = acceptable performance; red = unsatisfactory performance. The values of the various indicators falling inside the inner circle should be considered as values representing not acceptable performance. A system expressing these values should be considered as operating outside the viability domain (in relation to the chosen set of indicators).

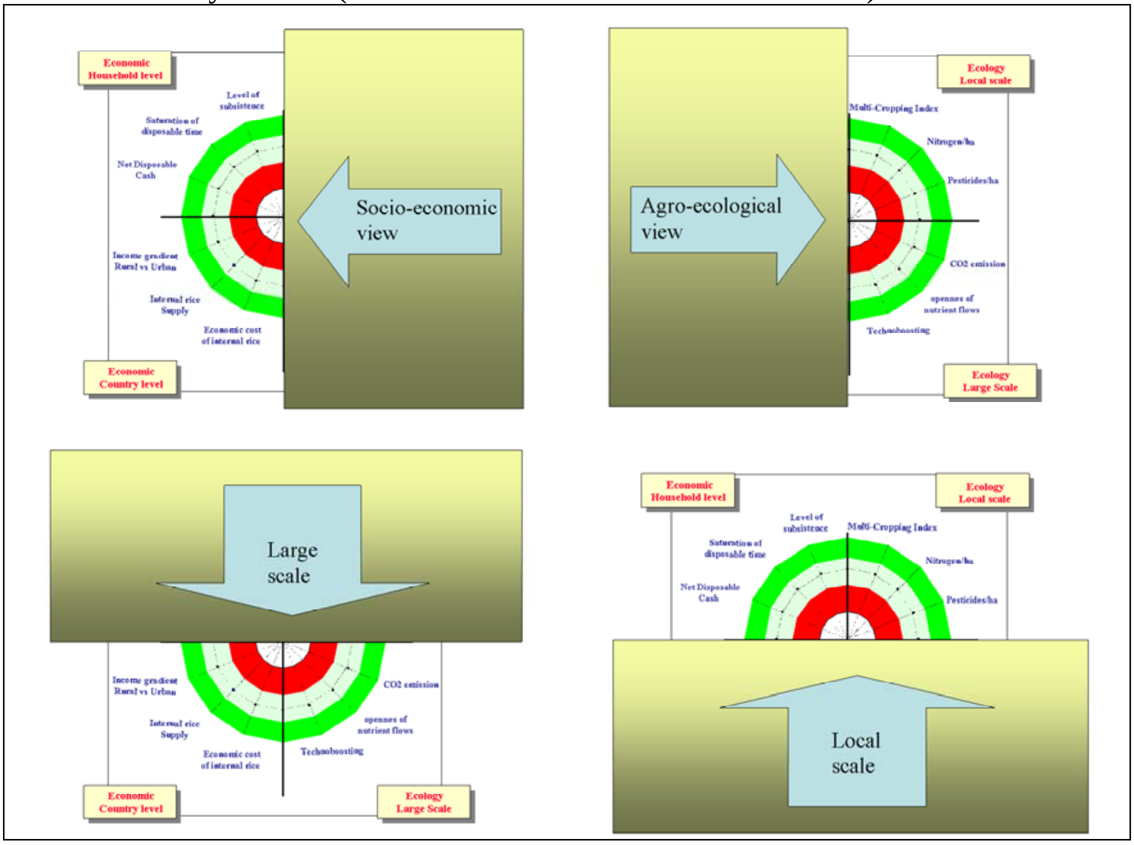

Figure 3:Multicriteria Space used to define the performance of a farming system

A more detailed discussion of this particular system of characterization is available in Giampietro and Pastore, 1999; and more in details in Giampietro, 2003. An overview of available methods of graphic representation for generating an integrated analysis of the performance of farming systems is given in Gomiero and Giampietro (2005).

The choice of the various indicators to be included in this Multi-Objective Integrated Representation (MOIR), obviously depends on the specific case study considered (the objectives of the analysis!). In the example illustrated in Figure 3, the indicators included in the upper-left corner were considered as relevant by the farmers, in the lower-left corner were indicated as relevant by the Chinese officers involved in the project in relation to the policies of development carried out by the Chinese government. On the upper-right quadrant we included indicators of environmental impact referring to the local level (crop-field level), such as soil health, load of pesticides and nitrogen, fractal dimensions of cropping fields. On the lower-right quadrant we included indicators of environmental impact referring to a larger scale (e.g. CO2 emissions, ratio colonized non-colonized land for protection of biodiversity, leakage of phosphorous and nitrogen in the watershed exported to downstream ecosystems) etc.

1.3. Bridging different representations of performance across levels

As observed in the introduction, it is relatively easy to organize different indicators of performance (of the type illustrated in Figures 1, 2 and 3), by gathering the data needed. However, what is difficult is to obtain is an analysis of the interlinkages among these indicators. That is, how and why if one tries to improve one of these indicators, one should expect a re-adjustment also on all the others. In relation to this point, in the previous applications of the MuSIASEM approach, it was possible to establish a method capable of establishing bridges across processes taking place at different hierarchical levels. This method was able to generate bridges across levels when operating within the same farming system typology. Again, in order to avoid complicated and tedious theoretical explanations (which are available, together with the data and results in the published papers referred above) we provide below a few examples of the results.

The research question was, how to establish a bridge between: (a) a given representation of performance of a household type (in Figure 1); and (b) the performance of a village (in Figure 2). As explained in detail in the Chinese case study (Giampietro and Pastore 1999, Pastore et al. 1999) in another application referring to uphill Vietnam (Gomiero and Giampietro, 2001), and in more general terms in a dedicated book (Giampietro 2003), it is possible to obtain such a bridge (establishing a scaling across two representation referring to two different levels) by using the concept of “metabolic pattern” which is based on the definition of typologies of metabolic elements.

In practical terms, the study carried out in China found out that the various farmers belonging to a given typology of farming systems were not allocating randomly their hours of human activity accounted in the category “human activity in farming”, and their hectares of land uses accounted in the category “colonized land for agriculture”. On the contrary they were expressing patterns of allocation of both human activity and land uses over a given set of typologies.

The various types were generated by a few possible bifurcations in the decision space of farmers:

(a) the ratio of working time allocated on farm (associated with agricultural land uses) versus working time off-farm (independent from land uses);
(b) within the categories of human activity dealing with agriculture – the ratio of working time allocated to subsistence (subsistence land use) versus cash crops (cash-crops land uses);
(c) within the categories of land uses either subsistence or cash-crops – the chosen mix of crops (determining a relative profile of investment of human activity).

Again to cut a long story short, we found out that we could express the characteristic metabolic pattern of a village (considered as a given number of people belonging to a given farming system typology, or as a given number of hectares belonging to a given farming system typology) as determined by the relative mix of characteristics of lower level elements – the relative size of the different households (belonging to different typologies) making up the village. The logic of this method of scaling is the following. The generation of a household typology within a given farming system is generated by a set of constraints affecting the option space of individual households. These constraints are determining the option space of individual households, that is, constraints define the set of possible household types. This is illustrated in Figure 4.

After having accepted this point, we can characterize each typology of household type with a set of indicators of performance. Then, after having characterized the set of household types found in a farming system, it becomes possible to characterize the performance of the metabolic pattern of a village made-up of a given mix of household types by weighting the relative importance of the various types over their size.

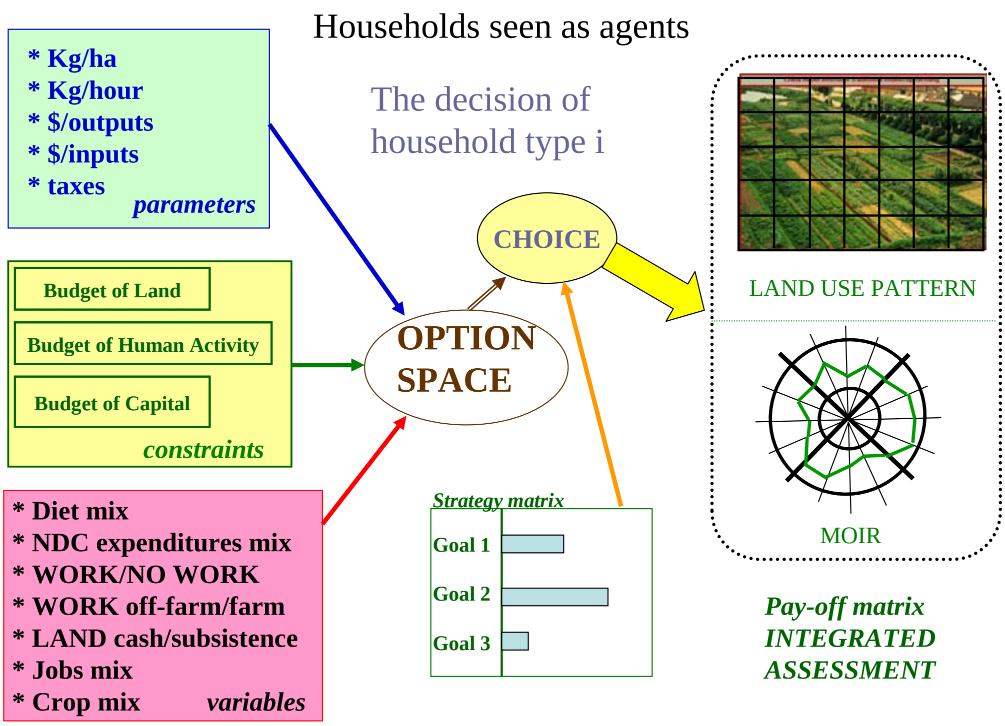

Figure 4: The set of constraints generating household typologies

That is, we can characterize the metabolic pattern of a village made-up of 30% of household type A, 50% of household type B, and 20% of household type C. This approach is illustrated in Figure 5.

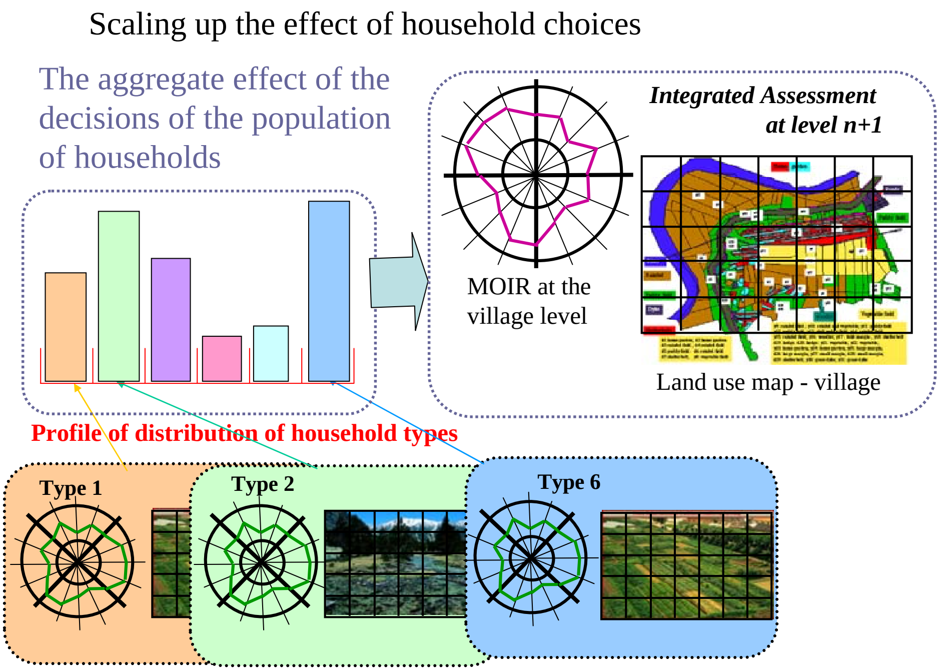

Figure 5: Scaling the integrated analysis from the level of households to that of villages

By doing this series of operations one establishes a correlation found in the farming system considered between: (A) a given representation of a profile of human activities; and (B) a given profile of land uses; and (C) a profile of performance in relation to a given package of indicators. This expected set of relations is illustrated in Figure 6, and it is essential to the analysis proposed in this case study.

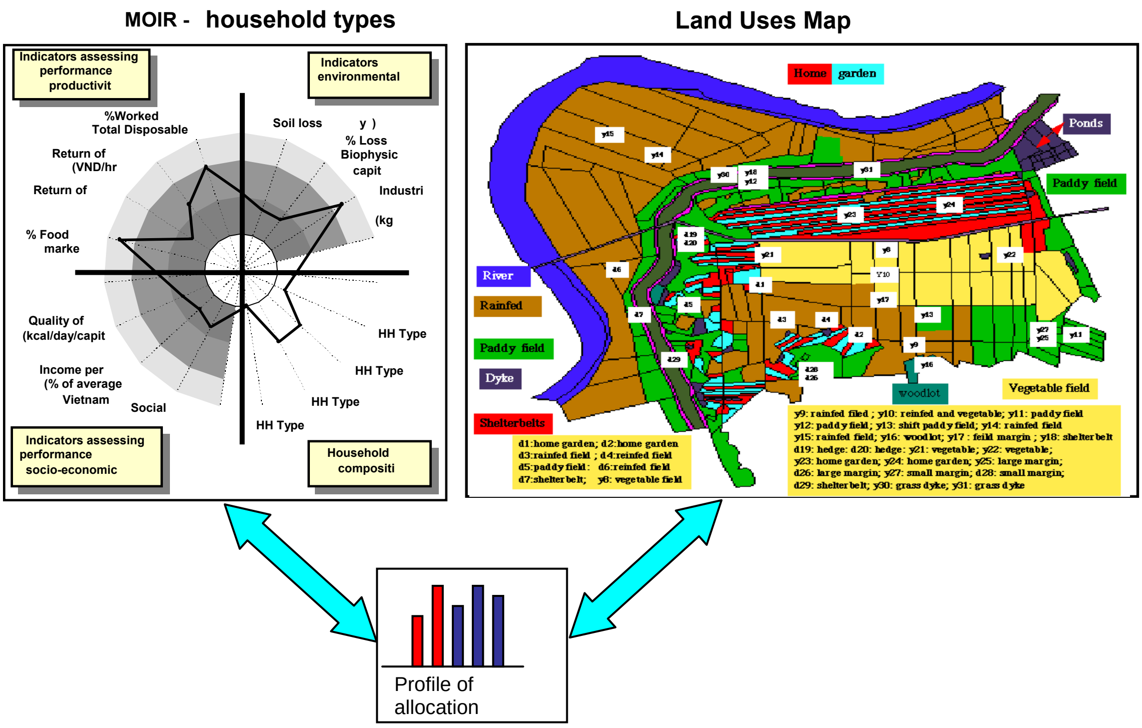

Figure 6: The expected relation between human activities and land uses in the metabolic pattern expressed in a farming system

1.4. The semantic bifurcation in the definition of size: studying ecological impact *vs.* studying socio-economic impact

As long as one remains within a homogeneous rural area, in which it is possible to assume a general consistence between the pattern of allocation of hours of human activity in farming and the pattern of allocation of land in the resulting categories of land use, we can say that we are remaining within the same typology of farming systems. This implies that we can use (within a certain range of approximation) a constant value for the population density, arable land per farmer, structure of population, crop mix, the average income of farmers, density of flows per hectare (crop yield, use of inputs, cost per hectare and gross revenue per hectare). This was the situation found in the study carried out in China (Giampietro and Pastore, 1999 and Pastore and Giampietro, 1999) and in another example of application of the MuSIASEM approach in Vietnam (Gomiero and Giampietro, 2001).

However, when enlarging the scale of the analysis, to arrive to the size of an entire region or an entire country, two important problems may appear:

1) ***The existence of heterogeneity in the types of farming systems –*** in this case it becomes impossible to use just a single farming system metabolic pattern (= a single mapping of a given multi-level matrix of human activity over a given multi-level matrix of land uses) to perform the scaling across levels. The existence of different typologies of farming systems (which is unavoidable when considering the activity of agriculture at the large scale) entails the existence of different categories required for defining what the farmers do – e.g. different crop mix, income of farmers, density of flows per hectare, crop yields, use of inputs, cost per hectare and gross revenue per hectare – and for defining the interface of the society with the context – e.g. population density, arable land per farmer, structure of population.

2) ***The difference between urban and rural typologies of land uses –*** the co-existence of rural and urban patterns of metabolism in modern societies implies a clear problem of scaling, since the density of the flows (money flows, energy flows, material flows) both per hectare and per hour of human activity in these two compartments are very different. When dealing with the integrated characterization of metabolic pattern in rural areas versus metabolic pattern in urban areas, we can find differences which in some cases are of orders of magnitude. For example, as illustrated in Figure 7 when considering the metabolic pattern in Catalonia (described in details in the case study of Catalonia for the EU Project SMILE) less than 3% of land use generates more than 95% of the GDP. The same non-linearity is found when considering the multi-level matrix of categories of human activity (less than 9% of the human activity is generating more than 95% of the GDP).

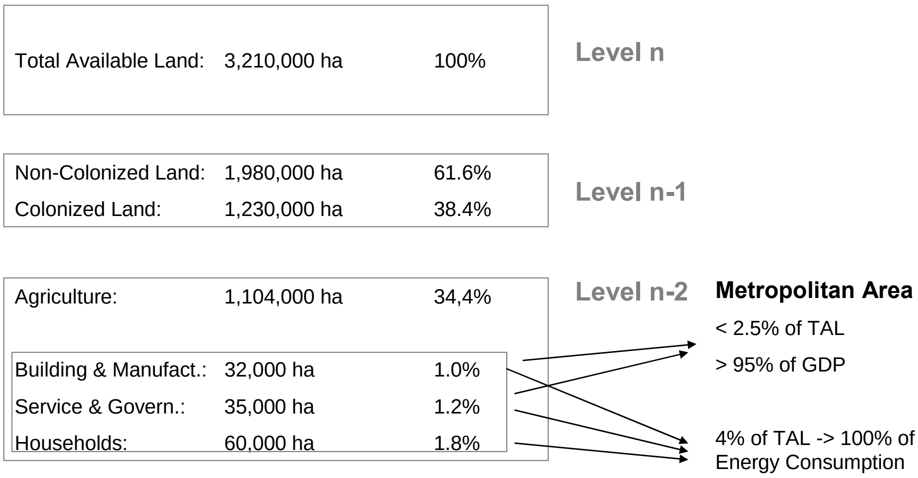

Figure 7: The non-linearity in the profile of land uses and in the profile of relative flows when considering the urban versus the rural metabolic pattern

This means that if we focus only on the 2.2% of land use in Catalonia used by the Industrial and Service sector, adopting the required resolution of analysis to make a distinction between different land uses in manufacturing, then we will unavoidably miss large scale features referring to the rest of 97.8% of the land in Catalonia. On the other hand, if we gather information crucial to deal with ecological issues and natural resource management referring to the 97.8% of land of Catalonia, we would miss fine-scale details useful to study pattern of land use within industrial polygons.

In conclusion, the problem addressed in this Laos case study is how to find a method of analysis capable of: (i) handling the unavoidable existence of different farming system typologies when considering geographic differences at the large scale; and (ii) handling the difference between rural and urban metabolic patterns, when extending the integrated analysis to the whole country Laos (including basically the capital Vientiane).

1.5. The goals of this application: developing the multi-purpose grammar for the integrated analysis of the metabolic pattern of Laos

The concept of grammar and multi-purpose grammar (establishing a set of expected relations between semantic – meaningful labels – and formal categories – to which we can assign proxy variable – over a given lexicon and production rules) has been discussed when presenting the MuSIASEM approach in previous documents.

Building such a grammar in this case study required first of all, establishing a semantic definition for the three labels – local, meso, macro – which were used to characterize the metabolic pattern of Laos across levels. These three labels were necessary in order to be able to choose an appropriate narrative for the “scaling” of the quantitative representation:

- **The local level** - using two different semantic definitions of the size:
  A. Interpreted in terms of a ***small size*** of hours of Human Activity – the set of categories, the mix of categories and the amount of hours of Human Activity within a given typology of farming system – when considering the small level: the interface households/villages.

B. Interpreted in terms of a ***small size*** of hectares of Land Use – the set of categories, the mix of categories and the amount of hectares within the chosen typology of farming system – when considering the small level: the interface households/villages.

Therefore, at the local level, when operating within a given typology of farming system, the variable "population density" can be associated with the chosen typology of farming system, that is, it depends on the definition of the metabolic pattern expressed by such a typology of farming system. In fact, the identity of this typology of farming system establishes a link between a given set, a given mix and a given amount of hours of Human Activity (accounted over a given set of categories) and a given set, a given mix and a given amount of hectares (accounted over a set of categories of Land Use mapping onto the categories of human activities). The biophysical root of this link consists in the fact that the chosen set of categories of Land Use are required in order to be able to express the chosen set of categories of Human Activity. In relation to the concept of societal metabolism, we can say that the forced relation between FUNDS and FLOWS in the process of reproduction of the FUNDS entails a correspondence between the characteristics of the multilevel matrix of Human Activity (how the social system uses its time) and the multilevel matrix of Land Use (how the social system uses its colonized land). This expected relation translates into a pattern of metabolism (benchmark values for the density (per hour) and intensity (per hectare) of the different flows considered over the various compartments included in the multi-level matrix. That is, this expected pattern of metabolism can be considered to be a typology of farming system.

In conclusions, after having adopted this grammar for characterizing the farming system at the local level, we get a quantitative representation which provides two non-equivalent definitions of size for this system:

1) How many hectares of the expected land uses map onto 8.76 M hours (1,000 people x one year) of the mix of Human Activity characteristic of this farming system type.
2) How many people (or hours of expected categories of Human Activity) map onto 1,000 hectares of the mix of Land Use characteristic of this farming system type.

- **The meso level - using two different definitions of size:**

A. Interpreted in terms of a medium size of hours of Human Activity – associated with the number of people living in a geographically defined entity (in this study we consider three regions defined within Rural Laos – Northern Region, Central Region, Southern Region).
B. Interpreted in terms of a medium size of hectares of Land Uses – associated with the number of hectares included in the chosen geographically defined entity (in this study we consider three regions defined within Rural Laos – Northern Region, Central Region, Southern Region).

When dealing with this level we impose a different typology of constraint, which is defined from the outside. That is to say, the definition of the size in hectares (hectares of land in the region) and hours of Human Activity (people living in the region) for these three regions is "special" (it is not a typology). It does not reflect the effect of a given pattern of self-organization and self-reproduction. Rather, it just reflects the definition of geographic entities (regional compartments) decided by someone. This decision probably reflects historical events, institutional settings, political and geophysical factors. However, it should be noted that in this meso-level still we deal only with land belonging to the compartment “Rural Laos”. That is, the sum of the area of these three regions is equal to the total area accounted as rural Laos. With this choice of accounting, we can establish a bridge – using the interface local level and meso level – between the characterization of the metabolism of Rural Laos, the characterization of the three regions, and the characterization of the three basic “farming system typologies” found in rural areas of Laos. In this study we used three type of farming system typologies, for which we provide an integrated characterization (expected metabolic pattern per hours and hectares).

The integrated characterization of each one of the three regions is determined by a combination of the characteristics of lower level typologies. That is, the Northern Region is made of: x1 (fraction or percent) of Farming System 1; x2 (fraction or percent) of Farming System 2; and x3 (fraction or percent) of Farming System 3. Under the condition that the entire size of the whole – the given region – is the sum of the lower level elements [x1 + x2 + x3 = 1, or the three percents sum up to 100], we can scale-up the characteristics of lower levels metabolic system to the upper level. After characterizing the Northern region, the Central region and the Southern region in relation to the characteristics and the percentage of the typologies of Farming Systems composing them – at the meso-level – we can also express the characteristics of the entire rural Laos as determined by the relative characteristics of the three different regions. We apply again the same methodology, this time to scale-up from the characteristics of the regions to the characteristics of the entire Rural Laos.

In conclusion, the meso level can handle the heterogeneity of farming system typologies belonging to the larger category of “rural metabolic patterns”. However, by definition Rural Laos is only concerned with the analysis of rural metabolic patterns. That is, the concept of rural Laos implies the definition of set of categories of Human Activity which can be mapped onto a corresponding set of categories of Land Use, according to expected typologies (Farming System types).

- **The large-scale level - by using two different definitions of size:**

A. Interpreted in terms of the Total Human Activity of the whole – that is, it considers Laos referring to the whole population both urban and rural.

B. Interpreted in terms of the Total Available Land of the whole – that is, it considers Laos referring to whole area, including hectares of Non-Colonized and Colonized Land – the Total Available Land found within Laotian borders.

Finally, when considering the large-scale level, we have to address the existence of heterogeneity of metabolic patterns in relation to the coupling of categories of Human Activity and categories of Land Use to define density and intensity of flows. In fact, the urban metabolic pattern and the rural metabolic patterns require the use of different levels of resolution, since these two patterns are operating at very different values – benchmarks – of intensity (flows per hour of human activity) and density (flows per hectare of colonized land) of flows.

Part 2 Implementing the multipurpose grammar

2.1. An overview of Laos and the criteria to be used for its characterization

Lao PDR represents an ideal socio-economic system for developing the proposed approach, given the particular characteristics that this unique country can offer.

Laos is a socio-economic system in which the identification of the semantic elements and their functional relations is quite easy for the purpose of this analysis. Moreover, the lack of complexity of its economy – defined here as the very low diversity of tasks required for the production and consumption of goods and services – makes possible to generate quantitative data using very few typologies of metabolic pattern, without loosing too much accuracy. This fact is explained by the singular functioning of the country, which can be still considered a rural system. Its socio-economic structure is based on agriculture, and subsistence agriculture plays an important role within its economy. Laos is a country where about 73% of the population lives in rural areas, according to the last data of 2005 from Lao PDR National Statistical Centre (NSC, 2005). The scant foreign trade is based on natural resource extraction, basically wood products and electricity from hydropower. Agriculture, dominated by rice, accounts for about 40% of GDP and provides 80% of total employment (US Central Intelligence Agency, 2008). This assessment probably underestimates the value of the food and other services consumed by the local population in subsistence (out of market transaction). The Lao Expenditure and Consumption Survey 2002/03 from the NSC reveals that an estimated 99% of rural households is engaged in at least some form of agriculture (including livestock raising and fishing). Two thirds of the Lao households are basically in subsistence mode, complemented by some market production. In fact, 43% of the agriculture land is allocated to entirely subsistent production, with no market production at all (Grünbühel and Schandl, 2005). Finally, out of the total gross economic output, only 37% of the production values go to the market. For most agricultural products less than one third of the production is sold at the market (NSC, 2003). From all this data we can deduce that Lao PDR is a society where the rural communities experience a high grade of isolation in relation to trade and communications. The lack of infrastructures for transportation and communication makes spatial analysis very important in relation to future discussions over development policies.

Many uncertainties can be associated to scenarios of development of this country, and this makes Laos an interesting case study to implement the type of analysis made possible by the MuSIASEM approach. This country is one of the economically poorest in the world with very reduced infrastructure (it has no railroads, a rudimentary road system, and limited external and internal telecommunications). However, the room for economic growth is huge, its GDP has been growing as average 6% per year over the period 1988-2007, and it will join the World Trade Organization in the next few years (US Central Intelligence Agency, 2008). Moreover, Laos is situated in the centre of a very economically active zone formed by South East Asian countries such as Thailand, China, Vietnam and Cambodia. Some of these countries are emergent economies, which are getting a growing share of the global market. Due to the spatial location of Laos, geographically in the middle of them, and the natural resources just recently started to be commercialized (from 1986 until now only by foreign companies), the present situation represents for Laos a big opportunity to get integrated into a globalized dynamics, and an unavoidable big challenge.

The choice made now will constraints its future.

Finally, it should be noted that Laos has also an important opportunity of development based on tourism. Although the tourist activity is still incipient, there is good potential in this sense. Laos was #1 on "The New York Times' list of places to go in 2008 and it is recognized as "one of the last natural areas with authentic traditional communities living in it, being the main enchants as a place to visit". The new potential activities can be developed in different forms, including approaches like 'community based tourism' – an alternative to classic massive tourism. Laos represents an exceptional case to try to discuss alternative options of future development. This study offers a basic analytical tool, which can be used to offer relevant information regarding the integrated characterization across scales of possible scenarios of development.

2.2. Farming System level – looking for typologies

2.2.1 Overview

The present study has analyzed three different types of farming systems that are then used to characterize rural systems in Laos. The selection of these three typologies has been done with the aim of representing the three main types of farming system that can be used to characterize agricultural production in Lao PDR. As discussed in Part 1, the choice of organizing the characterization of rural system using typologies of farming systems – studying the differences found among different farming systems in Laos – makes possible to couple the resulting characterizations to spatial analysis. This approach, therefore, allows using potential combinations of different types or different profile of distribution of types to test scenarios.

In this application, the characteristics of the meso-level are determined by the characteristics of three main types of farming systems previously identified by other authors according to the type of production they undertake (Thongmanivong, 2004; Uhlig, 1988 in Grünbühel, 2004). The three typologies are:

- Farming System 1: it is characterized for a higher proportion of "slash and burn" practices. It is generally situated in uplands and farmers apply a system of rice intercropped with other vegetables along the year. They have some livestock and the level of production for self-subsistence is very high. They also have a high dependency on non timber forest products (NTFP) for food and income.
- Farming system 2: it is based in intensive paddy rice cultivation in the lowlands. They have a lot of livestock and they also practice some fishing and hunting for self consumption. In this farming system typology farmers use fertilizers and pesticides and they may have some motorized tools like motor ploughs.
- Farming system 3: these communities mix the previous two farming systems with commercial crops like coffee, tea, fruits and vegetables. Therefore, they have a higher dependency on the market for their production and consumption of goods. This type of farming system is located mainly in the southern region of Laos.

After having selected these three typologies of farming systems, by defining the semantic categories used for quantification, it is necessary to move to the quantitative characterization. As explained in Part 1, this quantification requires to: (a) characterize the metabolic pattern for each one of these typologies; and (b) define the distribution of the area of these typologies of farming system over the various regions of Laos. Obviously, the task of assigning quantitative assessments to the semantic categories chosen in the grammar represents a crucial step for the analysis, since the accuracy of the study depends on this information. In the present case study, we used for this task the information gathered in a previous European Project (SEAtrans), in which the researchers performing farming system analysis applied the principles of the MuSIASEM approach. This information was used to develop the characterization of the farming system types. Then in relation to the analysis of the distribution of the area of each typology (farming system) across the three regions, the profile of distribution across the regions has been estimated according to proxy indicators selected from the official statistical datasets. As explained in Part 1, what is presented in this study is far from being a reliable quantitative assessment, which could be used by policy makers of Lao PDR for discussing scenarios. Again we repeat that the exercise presented here wants only to indicate that it would be possible to generate a much more reliable integrated characterization across scales, similar to the one presented here, if more resources were invested in this type of analysis, making possible a more systemic and focused gathering of data.

2.2.2 The representation of characteristic of Farming systems at local level

According to the explanation given in Part 1 – we established a link between a given integrated characterization of performance of each farming system type and the resulting characteristics of the pattern of Land Use in the relative landscape. An example of this analysis – for Farming System 1 – is given in Figure 8 and can be related to the examples illustrated in Figure 5 and Figure 6.

In the overview given in Figure 8 we can see that: (A) the performance of the farming systems (characterized using an integrated package of indicators shown in the radar diagram) can be associated with (B) a given pattern of Land Use (which can be recorded using the set of categories of Land Use in agriculture, included in the grammar); and (C) a given pattern of Human Activity (which can be recorded using the set of categories of tasks to be performed in agriculture). This expected set of relations will determine the level of population density (persons/hectares) for each type of farming system, the level of coverage of food security with subsistence, the level of disposable cash, etc. That is, the overview given in Figure 8 summarizes for each farming system considered the performance at local level in both: (i) qualitative terms – by reflecting the perception of performance associated with the radar graph (this perception can be obtained using participatory processes to be sure that the selection of indicators reflect the opinions of the various social actors); and (ii) quantitative terms – by representing the metabolic flows in relation to the fund elements (density and intensity of the various flows across the chosen compartments).

2.2.2.1 Representation of performance in qualitative terms

Again the radar graph used here – on the left of Figure 8 – has the only goal to show the possibility of coupling to this type of analysis selected indicators used to characterize the system in relation to multicriteria indicators of performance. Since this qualitative characterization has not been carried out within an applied study, having the goal to answer real policy questions, we included a generic radar diagram based on four very generic criteria of performance, which are grouped within the four quadrants of the graph: socio-demographic factors, agricultural factors, land use, and economic attributes.

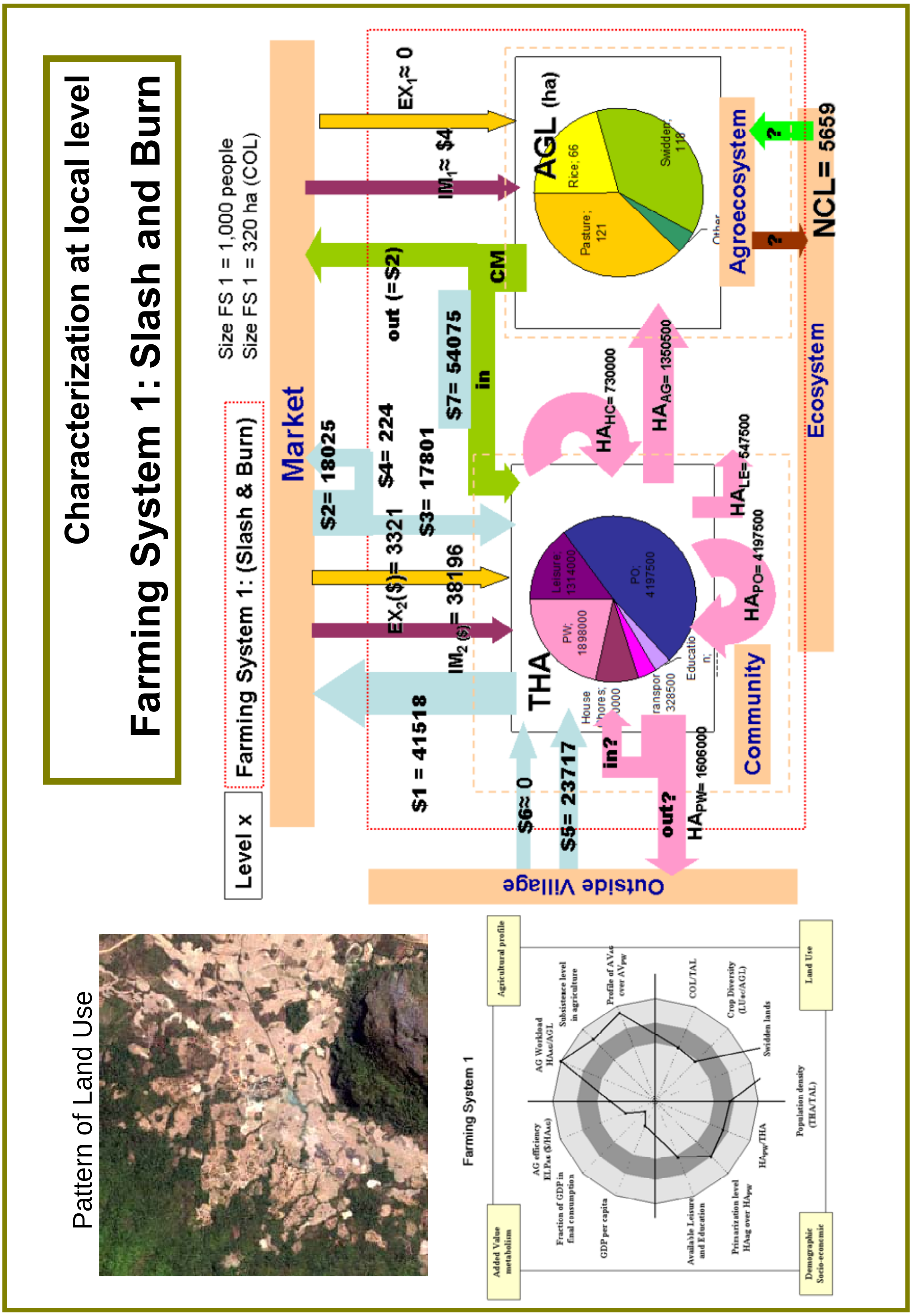

Figure 8: Metabolic Pattern of Farming System 1

For sake of comparison, the quantitative values for every indicator have been normalized according to the average values of the three farming systems, so now they are expressed in percentage terms. That is in this representation, the thick grey line in the graph represents this average value (100%), and we can observe easily how much each one of these indicators is better or worse – in each farming system typology – than the average of performance for the three Farming System values together.

2.2.2.2 Representation of the metabolic pattern in quantitative terms

The system diagram on the right of Figure 8 represents a mapping of the main relevant metabolic flows of a rural village in quantitative terms. The main elements in the diagram are two types of FUNDS: (1) the FUND Human Activity; and (2) the FUND Land Use. These two funds are used to construct two different Multi-level matrices over the same categories. Then, as discussed in Part 1, these two FUNDS are defining the size of the same system simultaneously in two non-equivalent descriptive domains (this is the main innovative feature of the MuSIASEM approach). So, the representation of the metabolic pattern of rural systems depends on: 1) the semantic choices made by the analyst, when deciding the categories making up the two multi-level matrices over the two funds (the elements/parts in which the analysis decomposes the farming systems) and 2) the resulting benchmarks characterizing the metabolism of the various FLOWS in density (flow per hectare) and intensity (flow per hour) over the two multi/level matrices. It is important to observe that the representation of the metabolic flows against the FUND Human Activity is useful to study socio-economic processes, whereas the representation of the metabolic flows against the FUND Colonized Land is useful to study how the pattern of societal metabolism is interfering with the metabolism of the ecosystems embedding the society. That is, the spatial location of human activities is generating a human-made landscape, which is affecting the original natural landscape. Put in another way, by adopting the MuSIASEM analysis we can establish a bridge between the socio-economic and the ecological reading in an integrated system across levels and scales. As we mentioned previously, the bridge is established when linking the two non-equivalent size of a system. For instance, in Figure 8, at the local level the relation is 320 ha of Colonized Land for every 1000 people living in Farming System Type 1 (observation referring the year 2003).

Another important fact concerning the use of this diagram is that the lexicon (the definition of the set of flows and elements represented) can be used for the analysis of other rural systems (as a matter of fact a few other applications are in progress using this same approach in Latin America). The semantic openness associated with the concept of grammar does imply the possibility of adjusting the definition of formal categories [e.g. the semantic concept “cash crops” has to be formalized in different ways, using different types of cash crops, in different farming systems around the world]. This implies that the basic multi-purpose grammar used to generate the flow diagram shown in Figure 8 can be adapted to other rural systems. This may require also including (or excluding) other flows – e.g. water flows in arid areas – depending on their relevance.

2.2.2.3 Dealing with the interaction with the context (external constraints)

Looking at the flows given in the graph of Figure 8, we find a few arrows getting outside and coming inside the black-box. These arrows are basically representing the interactions that the farming system has with:

1. *the biophysical context* – e.g. the natural ecosystem affected and affecting the rural system – which is represented by the Non Colonized Land (NCL);
2. *the economic context* – e.g. the effect of socio-economic interactions outside the borders

of the village. In fact, local people can invest some of the available human activity outside the farming system (e.g. off-farm work, leisure) which will be reflected by the earns of the work reintroduced to the community or income losses;
3. *market* – through which products produced in excess or products consumed are moving across the border to stabilize the existing metabolic pattern.

The general template of the set of expected relations indicated in Figure 8 includes an internal local market where the families exchange their production and services at village level (this can be analyzed by scaling down one level to the household level in a more disaggregated diagram), and inputs of money into the system, which is non produced directly by the work of the members of the community, such as subsidies, interest, or revenues from emigrants (this is the flow indicated as \$6 in Figure 8).

Therefore, the grammar we used for the analysis of farming system is based on a multilevel matrix of the FUND Human Activity – the various compartments HAi, indicated in pink in Figure 8, and 4 relevant flows (e.g. water is not included in this analysis): (i) Monetary flow (\$, in blue); (ii) Agricultural production (CM, in green); (iii) Material inputs (IM, in purple); (iv) Exosomatic Energy (EX, in yellow).

Additional flows may be added to this grammar to map additional relevant interactions of the farming system with the natural ecosystem embedding it. These additional flows should be selected in relation to critical impact generated by the farming systems on the environment – e.g. nitrogen and phosphorous leakage in the water table in high external input agriculture. In the case of Laos, the availability of data only allowed to track accurately the flows in monetary terms, so the formalization of the different flows is reduced to their equivalence in dollars, as the price of the flows if they would be exchanged in the market. Obviously, this is not good at all, for an analysis which wants to deal with the accounting of biophysical quantities. However, as explained before, the basic metabolic pattern expressed at the local scale has been checked in biophysical terms, in the EU project, the very simple set of economic activities in rural areas of Laos makes is possible to map money flow onto the relative flows of outputs and inputs, and finally, this study has the goal to check whether it would be possible to provide a characterization across scales and dimensions of Laos using the MuSIASEM approach, if one had research resources and adequate time.

2.2.3 Looking at different metabolic patterns of farming system

An example of characterization of the metabolic pattern referring to the Farming System 1 is presented in the flow diagram given in Figure 8. For rural systems we can define a mix of agricultural production (CM – Crop Mix: e.g. cereals, meat, vegetables, etc.) that can go either to the market to be exchanged for money (arrow \$2), or which can be consumed directly inside the village, as subsistence agricultural production. In this last case we can also write a virtual cash flow, equal to the monetary price, which would have be paid in the market for that subsistence production (the arrow \$7). From the money obtained selling the agricultural production in markets (\$2) one can have some quantity for the consumption of the people in the community (arrow \$3), and one part may be reinvested in the agricultural production (arrow \$4), to buy material inputs (IM_1 – Imported Inputs: e.g. fertilizers, seeds, pesticides, machinery) or energy to run the machinery (EX_1 – Exosomatic Energy: e.g. oil for tractors, electricity for pumping). In the case illustrated in Figure 8, the exosomatic energy spent in agricultural production is negligible since the traditional agriculture is the general rule without significant use of technical devices consuming Exosomatic Energy. On the other hand, when it is necessary to invest a certain amount of monetary flow into input for the agricultural production, the flow of money \$4 has to be taken out from the profit given by \$2.

The monetary flow \$5 accounts for all the earnings obtained in the village from working activities performed outside the agricultural sector. The combined input of monetary flows (\$3, \$5, \$6) makes it possible for the community to buy goods and services (IM_2 and EX_2) obtained from the market. They can also save in good years, but for many rural areas of Laos in average the savings and the debts accumulated in different years tend to average out, so we accounted, in first approximation, that the monetary input goes out from the village for buying goods and services from the market (\$1).

Crucial to this analysis of metabolic pattern is the break-down of the Total Human Activity of the community into different compartments (associated with functional tasks). Beside the human activity going into work in agriculture (HA_{AG}), divided in cash-crops (HA_{CC}) and subsistence (HA_{SC}) and in work off-farm (HA_{OF}), the majority of human activity goes in Physiological Overhead (HA_{PO}) and Household Chores (HA_{HC}), plus the residual of human activity going into Leisure and Education (HA_{LE}).

2.2.4 The three types of farming systems

Farming System 1 (Slash and Burn). The metabolic pattern of this Farming System is illustrated in Figure 8. The peculiarity of this Farming System is the big allocation of time to the agricultural work (71% of the total working activity), and the enormous part of crop land dedicated to swidden rice (37% of Agricultural Land). As we can observe in the package of indicators of performance, this system has harder working conditions, and a high level of production for self-subsistence. We can see also how the money flow reinvested into agricultural production is very low. That is, the level of capitalization of FS1 is really low, so we are dealing with a traditional, pre-industrial type of agriculture, with big amount of labour and low inputs.

Farming System 2 (Lowland Paddy Rice). The metabolic pattern of this Farming System is illustrated in Figure 9, where we can see that the agriculture is much more focused in the livestock and production of intensive plantation of rice. The output of crop is higher per hectare and per hour of work due to the better quality of the lowlands, where it is possible to have more than one harvest per year. In general, the biophysical characteristics of these lowlands makes it possible to cultivate a larger fraction of available land (more hectares of Colonized Land/ Non Colonized Land) and with higher intensity.

Farming System Type 3 (Cash Crops). The metabolic pattern of this Farming System is illustrated in Figure 10, where we can see that it is more focused on the production of commercial crops. This farming system must have available infrastructures for transportation and communication. Therefore, we can see that in this farming system agricultural production is no longer the only economic activity, as in the previous two farming systems. We find a lower level of subsistence and more investment in input for agricultural production.

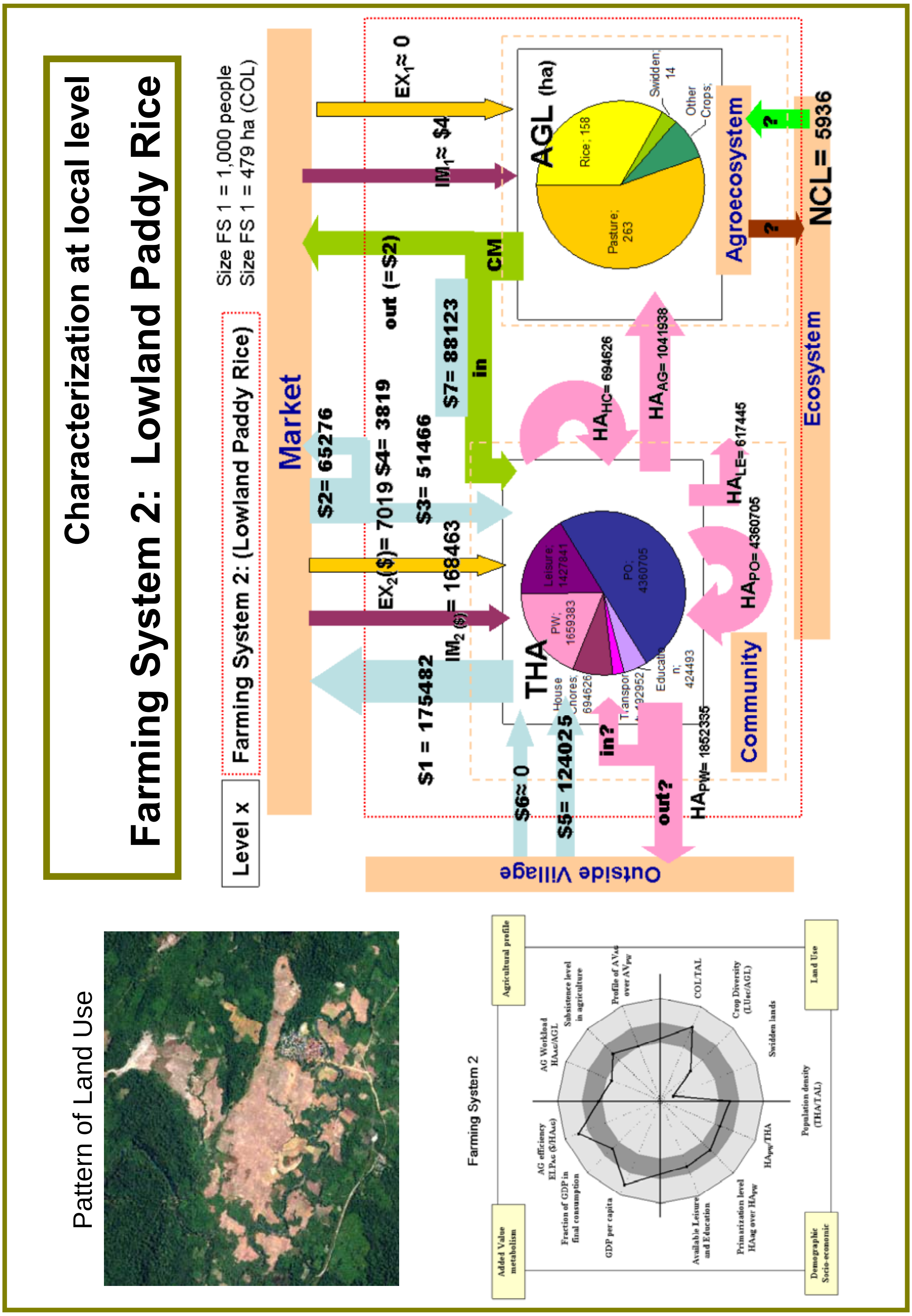

Figure 9: Metabolic Pattern of Farming System 2

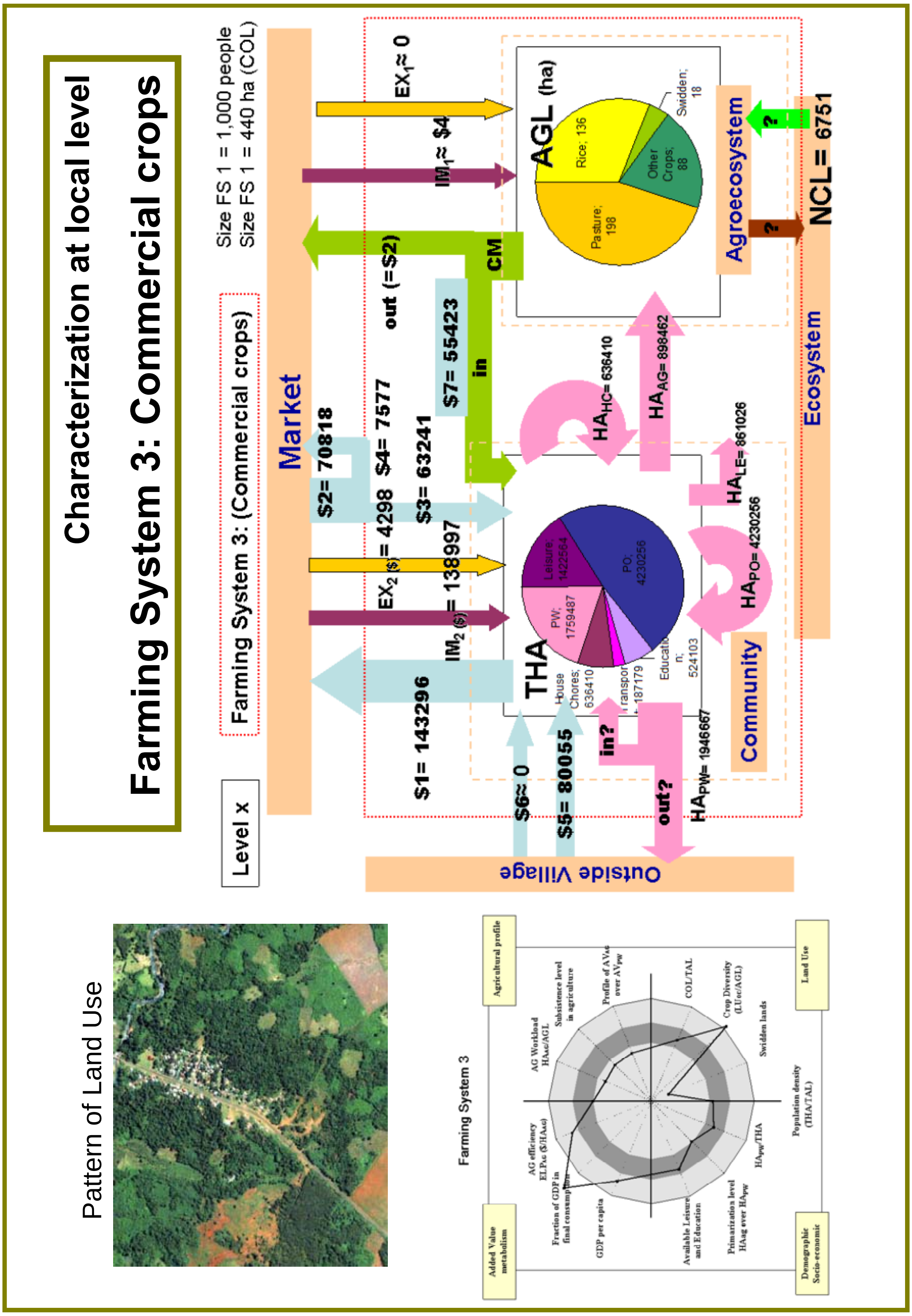

Figure 10: Metabolic Pattern of Farming System 3

2.2.5 Comparing the performance of the 3 Farming Systems

In this section we analyze the differences found among the three farming systems, from a multi-scale integrated perspective. We analyze the technical differences (technical coefficients) of the main productive sub-sectors determining aggregated differences across the three types of farming system. This comparative analysis is given in the two graphs shown in Figure 11 and Figure 12. For this comparison we use a bubble graph capable of visualizing at the same time: (i) the intensity of the flow per hour; (ii) the density of the flow per hectare; and (iii) the relative weight of every category/compartment considered in the grammar, indicated by the size (diameter) of the disk/bubble. The relative size of the bubble allows us to visualize how big is a given compartment at a certain level compared with the other compartments at that level (in the range of colours). The grey bubbles are for the Paid Work (including all the economic sectors), the green bubbles are for the Agricultural Sector in general, and the blue, orange and purple bubbles are for the three main subsectors inside the agricultural production: livestock, rice and other crops aggregated.

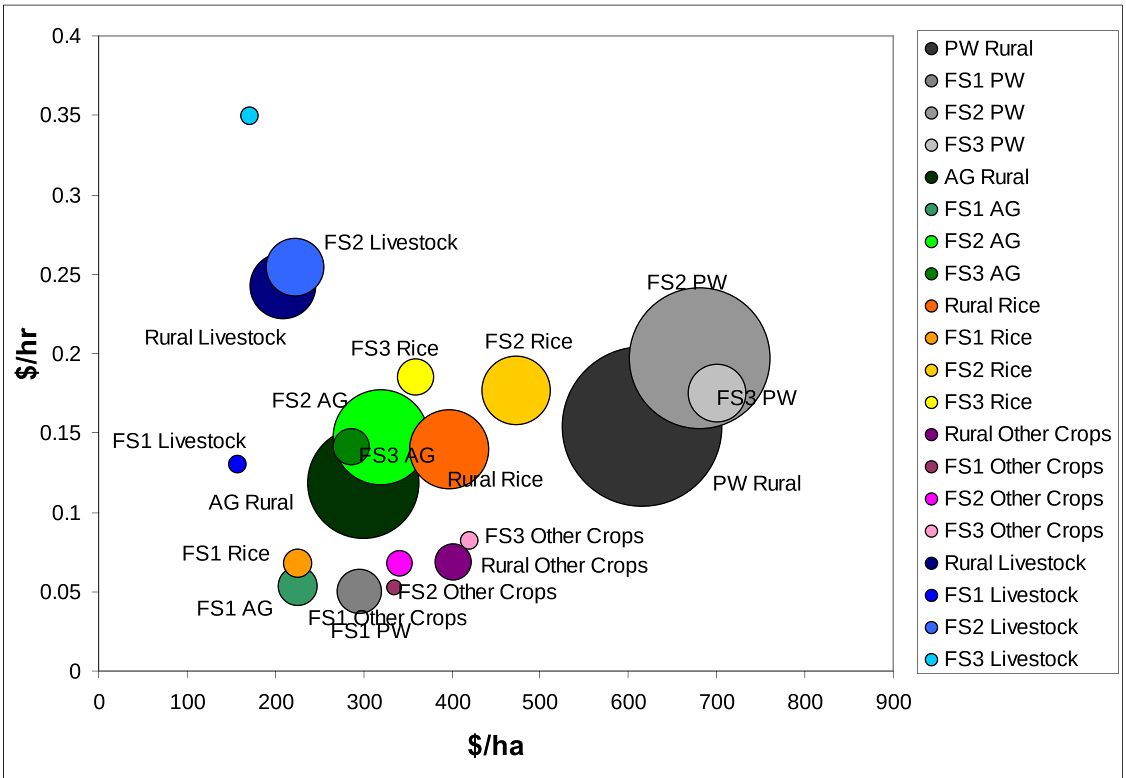

Figure 11: Intensity ($/hour) and density ($/ha) of elements the metabolic pattern (based on the intensity and the density of monetary flows)

Therefore the benchmarks represented in Figure 11 refer to the production of added value per hour of work and per hectare of cultivated land characteristic of the various compartments. The bigger is the size of the bubble the larger is the economic weight that the various types of elements play within the Farming System. Looking at these benchmarks we can clearly see how the elements associated with agricultural production have a much lower productivity per hectare than non-agricultural economic sectors. The reason is that the land occupied by non-agricultural economic sectors (building and manufacturing and services) is negligible when compared with the land used in agriculture. Moreover, because of the need of communication and transportation, non-agricultural economic activities tend to be concentrated in urban areas. A surprising characteristic of Laos is that we do not find a too much difference between the primary sector and the secondary sectors when looking at the productivity per hour of work. This means that the industrial sector in Laos is non developed yet and the non-agricultural activities are labour-intensive too, generating a low flow of added value, comparable to the level of agricultural production. As a matter of fact, rice production is very intense per hectare and generates similar values of added value per hour to the pace associated with economic activities not related with agriculture.

Looking at vegetable crops we can observe that they are very demanding in terms of work (generating also a low level of $/hr), and that their production is quite intense and concentrated in few hectares. This is the expected pattern for the typical vegetables grown in home gardens like carrots, pepper, tomatoes, etc. The opposite pattern is found for the livestock sector, with a very high productivity per hour of work, given by the low demand of work to raise the cattle compared with the high price of meat. Clearly, this is paid for in terms of a large requirement of land for pastures to be able to feed the animals, so the monetary flow intensity per hectare is very low. Analyzing the performance for the three types of Farming System, we can see that the FS Type 2 has by far the highest value for the different agricultural productions. It also has the highest intensity per hour of work and density per hectare of colonized land. On the contrary, the FS Type 1 has levels of density and intensity of flows much lower, when compared with the other two FS types. The bubbles representing the performance of this farming system are all close to the bottom left corner of the graph. The FS type 3 is more or less in the average values, maybe due to its mixed characteristics described in section 2.2.4.

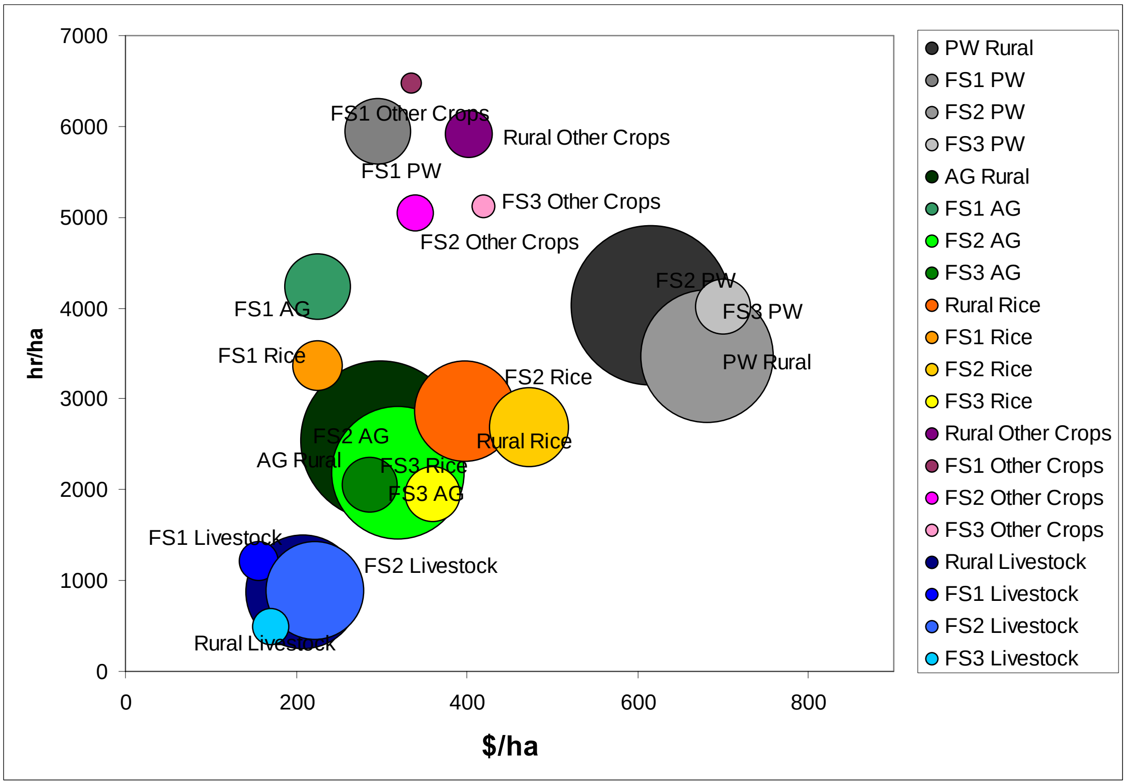

Figure 12: Ratio over funds (hour/ha) and density ($/ha) of elements

Regarding the link between socio-economic performance (money flows per hour of human activity) and environmental impact associated with land use, we provide, in Figure 12, a different view of the comparison given in Figure 11. In this graph we represent the hours of labor input needed per hectare (on the vertical axis) against the economic outputs per hectare (on the horizontal axis). The size of the bubbles represents the size measured in total hectares of each one of the considered elements. In this graph, the area of the graph on the right bottom (equal to a high density and a high intensity of monetary flows) can be associated with a good economic performance.

In relation to this hypothetical target, we can see clearly the trade-off between the very high labour requirement per hectare of cropping (with a low land demand) versus the very high land requirement of cattle production (with a low labour demand). The graph shown in Figure 12 confirms the observation made in the previous Figure 11. The characteristics of analogous subsector (the position of the bubbles of similar colours) tend to be close in terms of density and intensity. This means that the overall characteristics of the metabolic patterns associated with the different types do not depend too much on external factors (such us climate, soil quality, topography), but rather on the mix of productive elements (in particular the inputs introduced to boost production). At this point, we can hypothesize with these general results that the external factors are limiting the possibilities of development for the different types of agricultural subsectors (i.e. rice, livestock, other crops) in the form of constraints, rather than affecting the productivity rates. In other words, the biophysical factors are external factors defining the types of agricultural crops that can be grown in a certain system. Within this option space, the rate of productivity is given by the amount of inputs introduced (such as labor, water, fertilizers, machinery) – these are internal factors controlled by socio-economic variables.

2.3. Scaling-up in the farming system: from the local level to the meso level

2.3.1 How to scale-up in relation to a geographic criterion

The information used to characterize the metabolic pattern of different farming systems can be used to characterize the metabolic performance of selcted geographic areas. The process of scaling up the information to higher levels is based on the use of the expected values for each typology of farming system – expected values per unit of size – which can be weighted over the geographical area using the relative size of the various typologies.

From a top-down approach of spatial analysis, we can first calculate the proportion of Colonized Land and Non Colonized Land (COL/NCL) within each one of the regions (the entities defined as meso-levels). Then, for each one of the regions one has to define the distribution of typologies of Farming Systems, which must cover the total amount of Colonized Land in the selected region. In this application we have chosen a division in three regions: North, Centre and South, which coincides with the main geographic regions of the Laotian administrative divisions.

Figure 13 shows the calculation of the relative ratio of hectares of COL/NCL (colonized land versus non-colonized land) within each one of the three regions of Laos. This analysis has been performed using the relative amount of hectares of Colonized Land, which belongs to the different Farming System typologies.

After having determined the quantitative information shown in Figure 13, it becomes possible to scale up the characterization across geographical levels. That is, we can express the area of each region as a combination of three farming systems types, determining the mix defined by the relative size in percentage of the whole. This process of scaling from regions to the whole Rural Laos is illustrated in Figure 14.

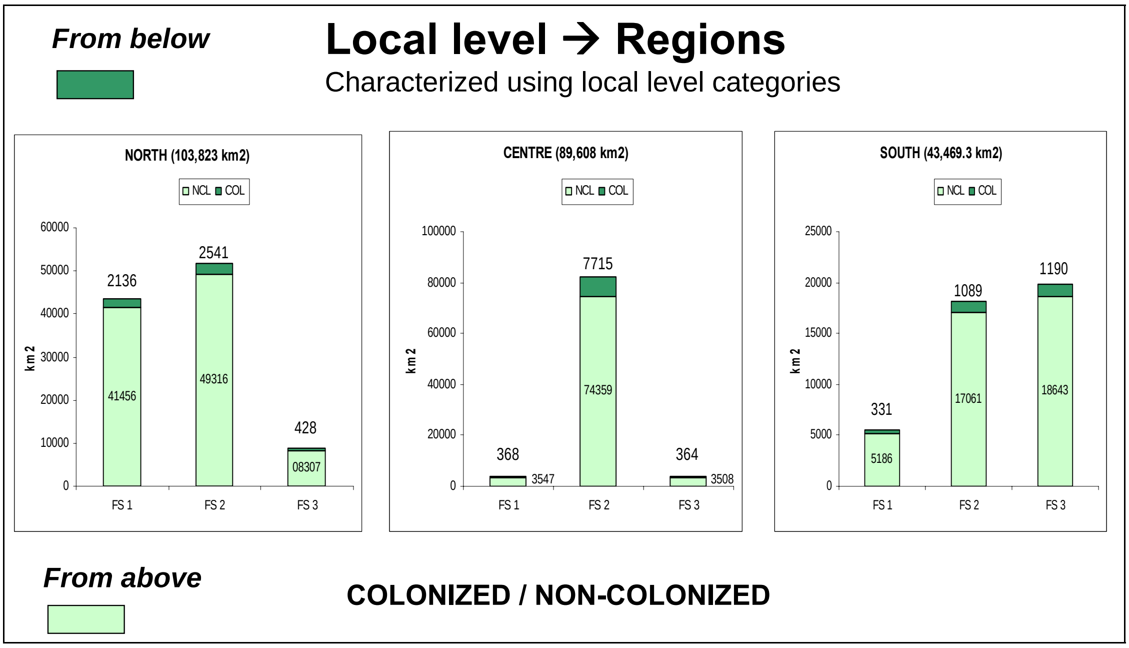

Figure 13: Distribution of Colonized Land against Non Colonized Land in Laos in relation to the 3 chosen farming systems

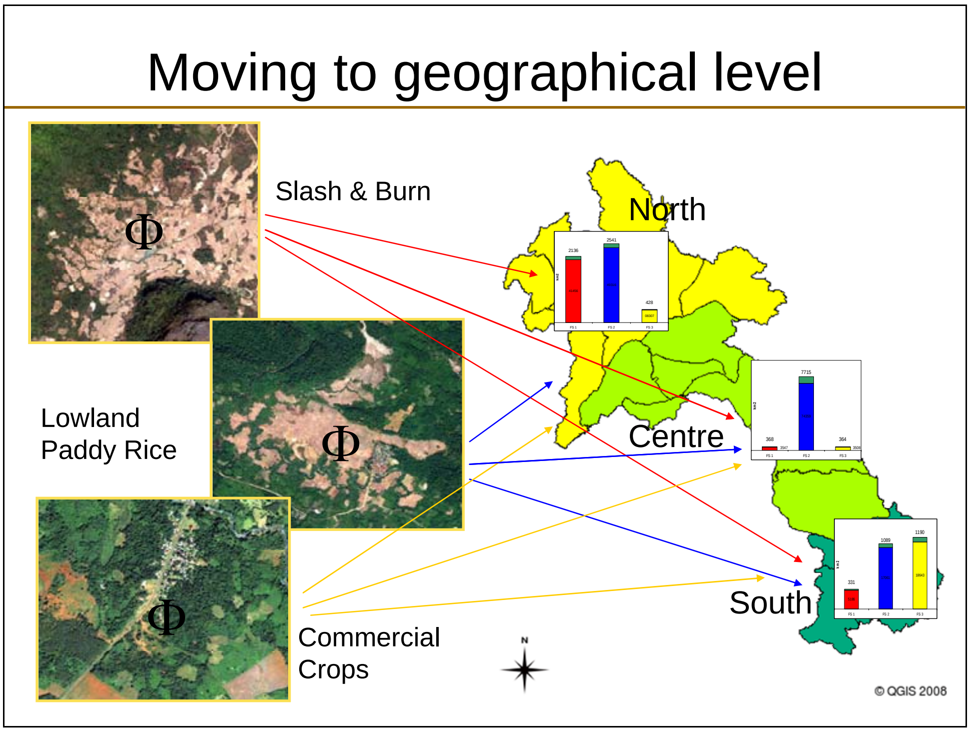

Figure 14: The distribution of the chosen three farming systems types over the three geographic regions (North, Centre, South)

Once the distribution among the geographical space of Farming Systems has been calculated through the Land Use information, the rest of information concerning the analysis of the FS at local level, as it was previously shown, can be extrapolated to the selected regions. For instance, the performance of the agricultural production of the FS Type 1 can be multiplied by the quantity of all the hectares colonized using the metabolic pattern associated with FS type 1 present in that region. A scheme showing this process can be observed in Figure 15.

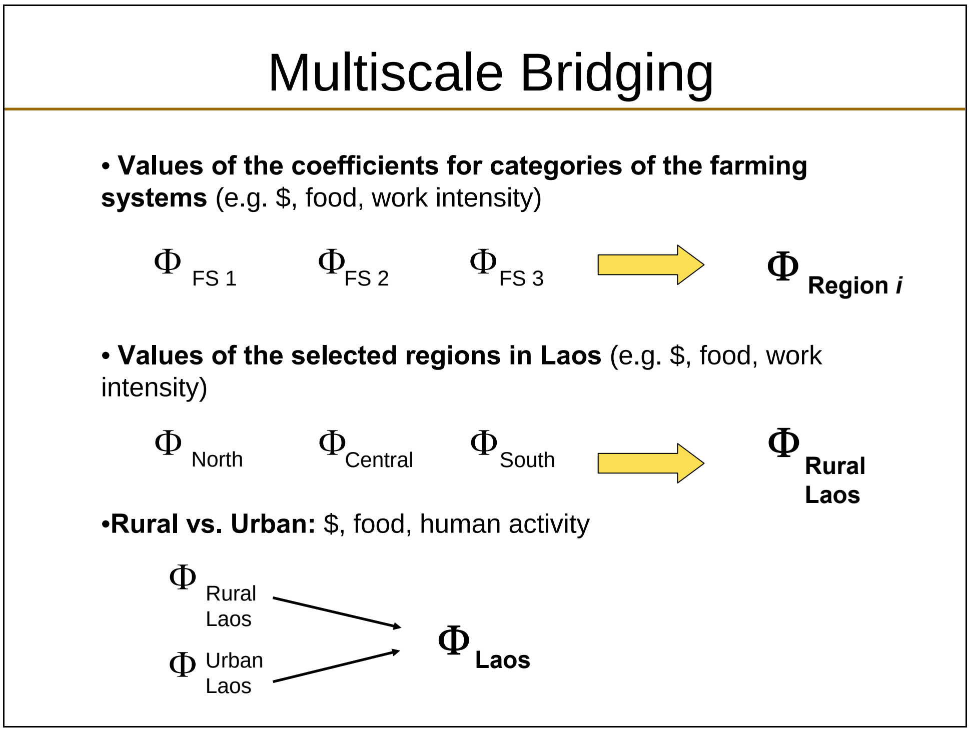

Figure 15: Scheme visualizing the scaling up of the flows densities the upper regional levels

2.3.2 The possibility of using alternative criteria for scaling

The meso level chosen in this study is based on the division of Laos into three major administrative regions, composed by few provinces each one. However, other geographical divisions can be made depending on the goal of the analysis.

For instance, instead of using just three regions of Laos, we could have used a more disaggregated administrative division such as the provinces (assuming the data for this higher level of disaggregation are available). In particular, the potentiality of the Geographic Information Systems (GIS) makes possible to explore a large number of categories for alternative analysis, which can be used to carry out more focused analysis. In relation to this point, Figure 16 illustrates some examples of other possible criteria, which could be used to carry out a more sofisticated spatial analysis. For example, through the buffer analysis one can select those places close to some key geographical points [e.g. villages within 200 meters from a road; the cities with access to navigable rivers]. With such division, one can characterize the differences in performance of the villages that are isolated compared to those ones which have access to road. In the same way, one can study the differences between towns undertaking commercial activities through water canals and towns having only terrestrial access.

The capacity of identifying key geographical features and be able to study separately specific differences in metabolic patterns translates into an incredible potential for scientific analysis of development options. In this way, it becomes possible to identify what is happening and where is happening, by establishing hidden relations and explanation between possible factors affecting the performance of systems. It is not only important to know what is the problem but also in which places it is located. An integrated analysis of metabolic pattern coupled to GIS makes possible to focus on very relevant policy issues, simply because different things happen in different places in different ways. It is not only pertinent, but also imperative to be able to study this obvious point.

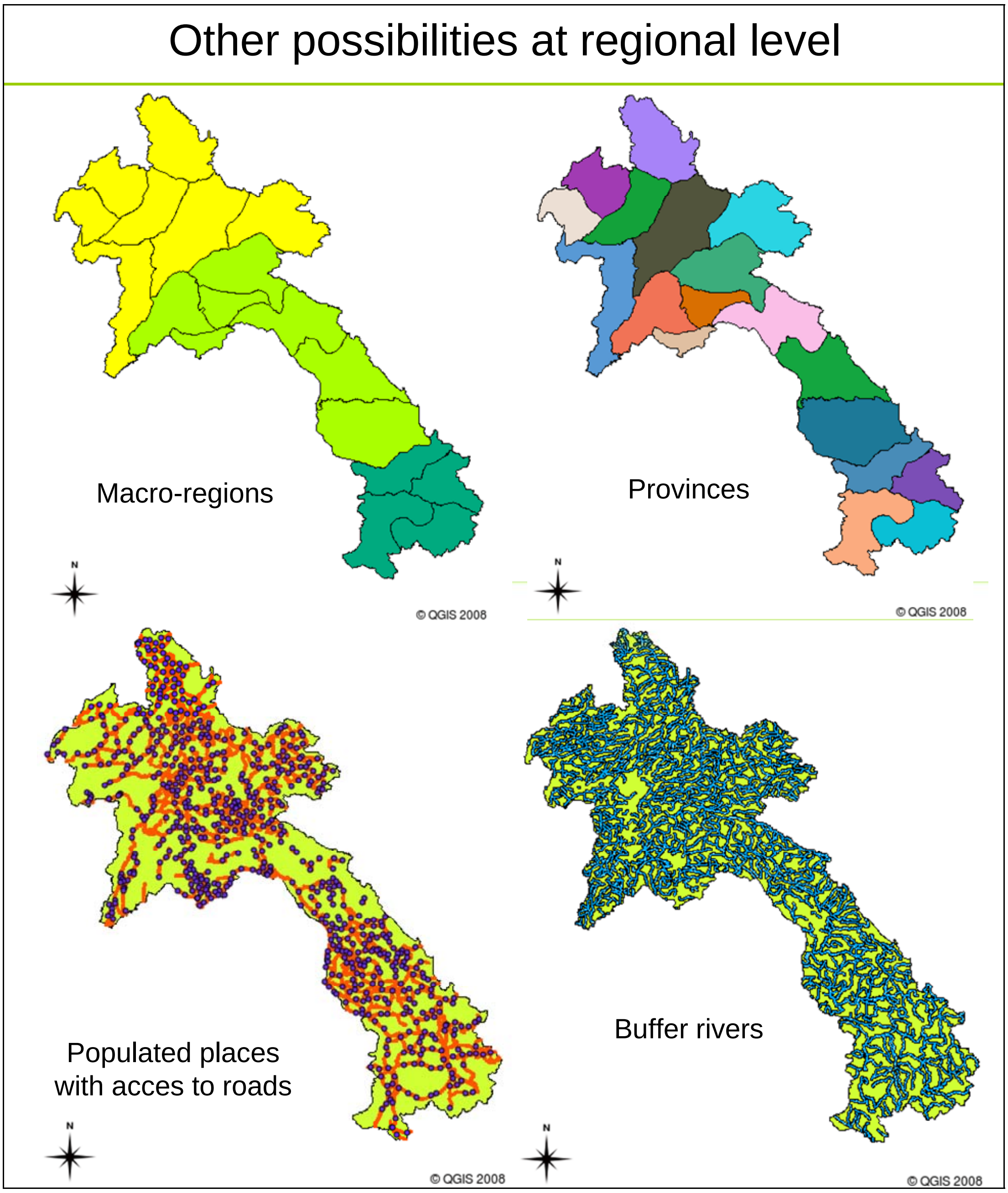

Figure 16: Alternative definitions of geographical regions for the meso-level

2.3.3. Comparing the performance of the 3 geographic regions

As done for the comparison of the 3 Farming Systems (in section 2.4) we provide now an integrated analysis of the characteristics of elements determining the performance of regions. The results of this comparison are presented in Figure 17 and 18. For these comparisons we are using the same type of bubble graphs used to compare the performance of the three Farming System Types (Figures 11 and 12). Actually, we even kept the same code of colours for labelling the different sub-sectors.

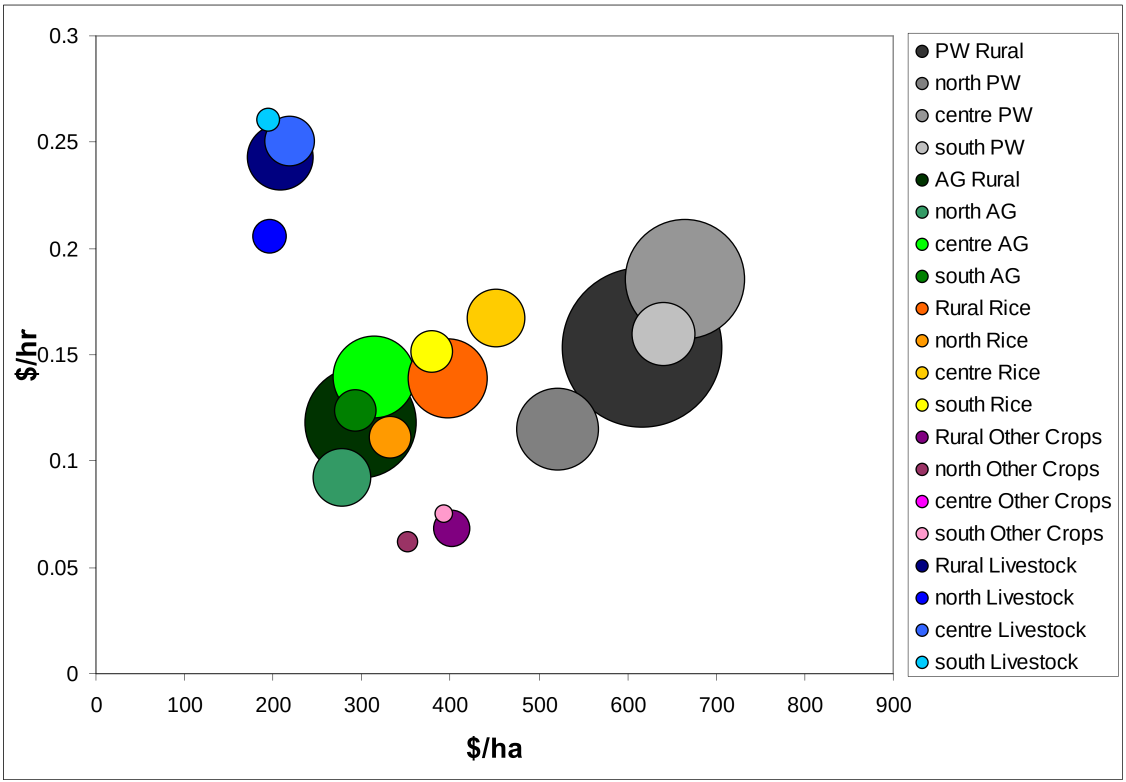

Figure 17: Intensity ($/hour) and density ($/ha) of elements of the metabolic pattern (based on flow/funds: $/hour - intensity - and flow/fund: $/hectare - density)

In Figure 17 we can see the productivities (intensity and density) for different economic categories of Land Use and Human Activity – the flow per hour of work and per hectare – used in the agricultural sector of these regions. The size of the bubble accounts for the GDP in the region. Also in this example, we can see a tendency toward the formation of clusters in the area of the graph of bubbles of similar colours. This seems to indicate that the differences between regions are smaller that the differences found in Figure 11 when comparing the different Farming Systems. The explanation of this fact is simple, since the three regions are made up of a combination of the three FS types, the differences in performance among these three regions decrease. We find that the metabolic pattern of the Northern region is lower in both $/hr and $/ha (due to the larger extension of FS 1) in its colonized land. The metabolic pattern of the Central region is quite high compared with the others and the Southern region is in the middle. Again the explanation is simple, since in the Centre is the FS 2 which is the most important and in the South is the FS 3.

In Figure 18 we characterize the performance of the metabolic pattern in terms of the requirement of labour input per hectare (vertical axis) and the productivity of the various sub-sectors per hectare (horizontal axis), with the size of the different bubbles representing the total amount of hectares in production. In this graph, we can see clearly the clusters of bubbles belonging to same category (with similar colour).

At this point we can drive some general conclusion of a general pattern going through the various graphs shown so far: Figure 10, Figure 11, Figure 17 and Figure 18. There is an obvious link between the characteristics metabolic benchmarks of elements and the characteristic metabolic pattern of the farming system type. Then there is the same link between the characteristics of the metabolic pattern expressed by a region and the characteristic metabolic pattern of the farming systems found in that region.

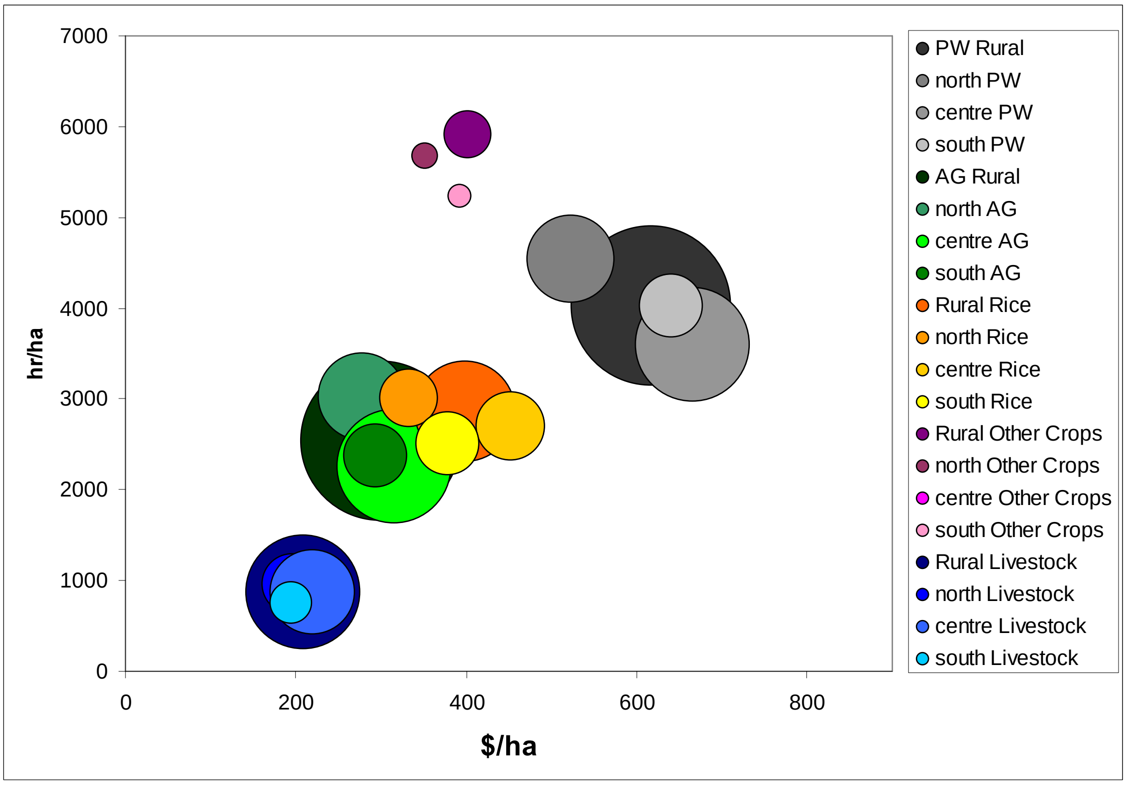

Figure 18: Characteristic benchmarks of elements of the metabolic pattern (bases on fund/ fund – hour/hectare – and a density – flow/fund)

2.4. Moving up to another step: characterization of the rural Laos

The following step has been that of scaling up the analysis to the entire rural Laos. This step requires the aggregation of the various characterizations obtained so far for the three different regions into the characterization of the entire rural Laos. Again, we use the same mechanism adopted before, but in this case this operation is easier because, by definition the rural Laos is the sum of the area of farming systems found in the three regions. That is, we have just to sum the hectares of the different farming system types found in each region, into an overall sum of the hectares of each one of the three farming systems for the whole Laos. This is illustrated in Figure 19.

At this level of aggregation we can perform a double-check on the quality of the assessment by using simultaneously two different data sources. The overall values of performance of the agricultural sector, found using the characteristics of farming system perceived and measured at the local level (studies carried out at the farming system level), have to result consistent with data coming from a top-down approach (national-level statistics on land use, agricultural production, farmers income, etc.).

At this point it becomes possible to represent at the national level the metabolic patterns of Rural Laos – by combining the values found for the three types of Farming Systems found in Laos. That is, we can reproduce the characterization of the farming systems – referring to the local level – illustrated in Figure 8, Figure 9 and Figure 10 to a national average referring to the whole rural Laos.

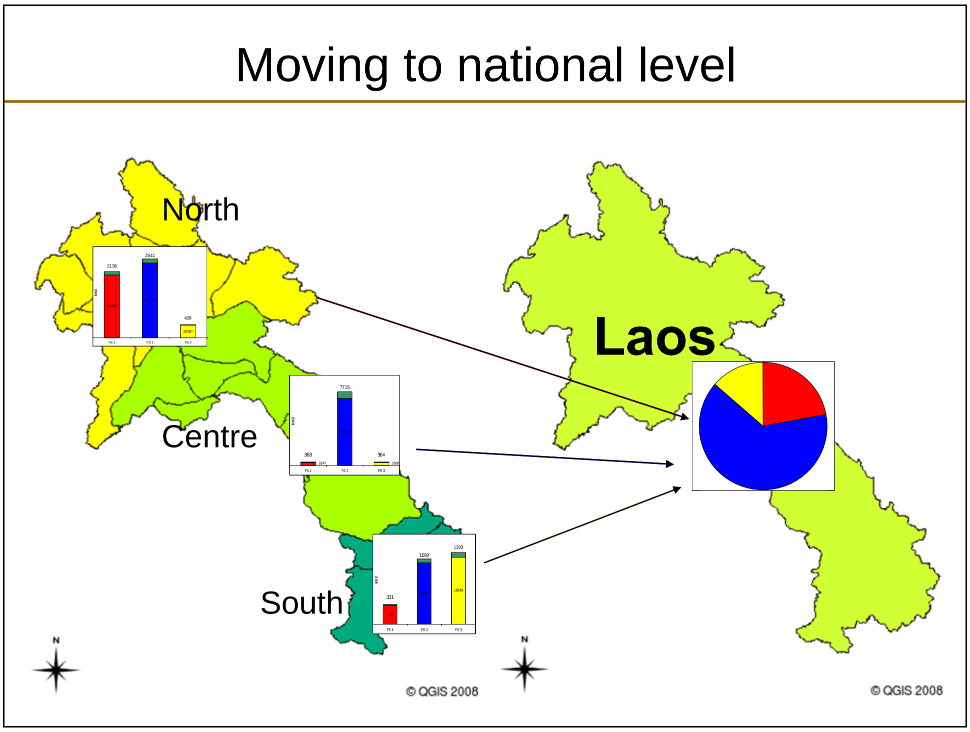

Figure 19: The scaling-up of regional information to rural Laos information

An example of the metabolic pattern of the whole rural Laos is given below, in Figure 20. This metabolic pattern would be found in a "virtual Laotian village" of 1000 persons, which would be operating according to the average values of productivity (intensity and density of flows) found for rural Laos. Since the Farming System 2 is the most abundant in terms of land use in Laos, we find in this numerical diagram a big amount of land destined to pastures. However, one has to note that this metabolic pattern is not associated with a real external referent [it is not determined by the set of constraints described in Figure 4]. Rather the value of the number reported in this graph are just the final result of a process of scaling, which has been determined by the aggregation across levels of the effects of different metabolic patterns (by mixing apples and oranges).

In spite of this caveat, we can still use this average representation of a virtual village of "rural Laos" to make general statements about the performance of the agricultural sector of Laos. In particular, we can notice that in rural places the Laotian society still relies heavily on self-production of food. In fact, if we compare the monetary value of this output (the virtual market value of the crops used for subsistence) to the production destined to market, we find that subsistence crops would represent a 58 per cent of the total value produced in agriculture.

As we mentioned earlier, we could not find a reliable data set for characterizing the use of exosomatic energy in agriculture. However, by talking with those that carried out the EU project and from literature data we learned that the fossil energy purchased for agricultural production (EX_1) is negligible since Laos is particularly characterized for a very extensive and traditional agriculture with very little machinery use and most of power sourcing from the human force (endosomatic energy). Clearly it would be interesting, in a more detailed research, to investigate the role of agricultural input based on of fossil energy to boost the density and intensity of the flows produced in these pre-industrial systems. In any case, at the moment, it seems that fossil energy is not a relevant factor determining the performance of the agricultural sector. The money reinvested in agriculture ($4) is rather related to the material inputs imported from the market, such as construction material for agricultural buildings, tools, and natural fertilizers such as manure, etc. The amount of energy purchased for the general use in the rural communities (EX_2) it is shown in its equivalence in monetary units, and we use the same formalization of the measure of flows for the IM_2 accounting for all the commodities bought in markets for the community's use.

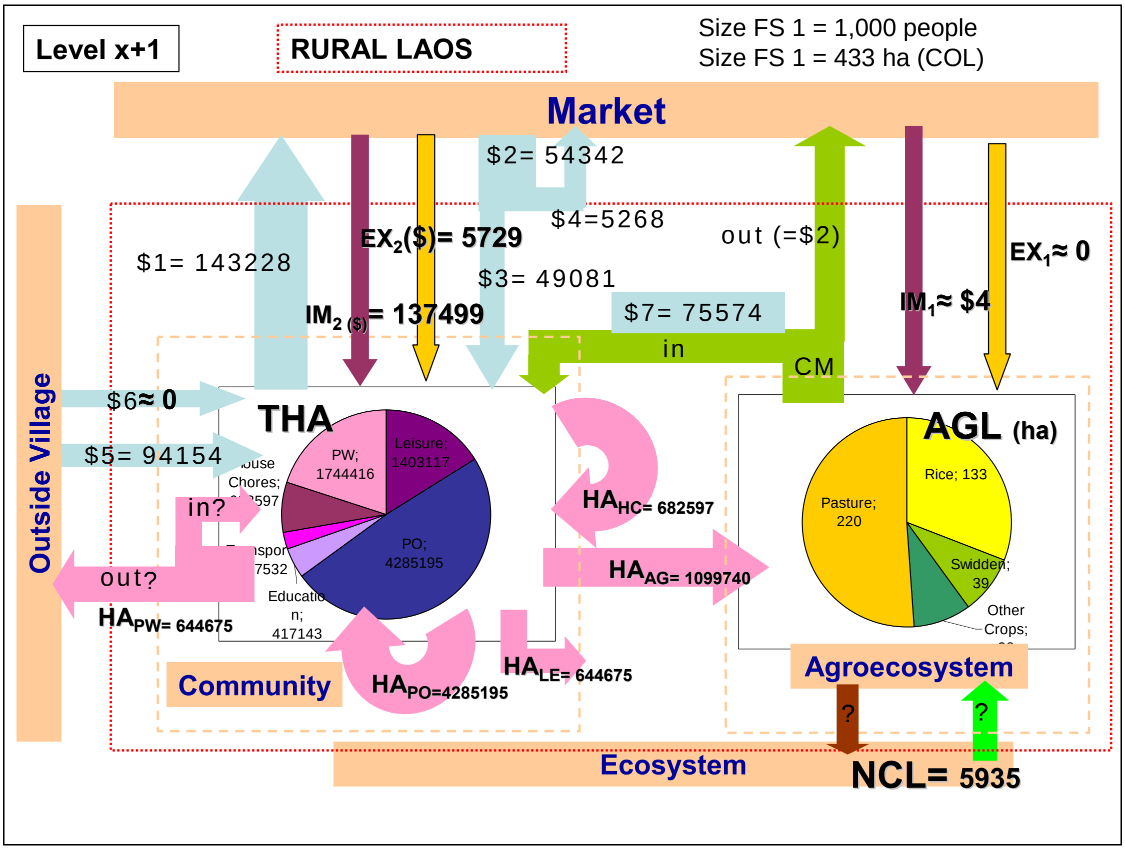

Figure 20: Metabolic pattern for a "virtual village" expressing the average characteristics of rural Laos.

One of the most interesting facts when we see the data from rural Laos is that although the population work most of the time in agricultural activities (63% of the productive time), the biggest monetary income for the rural population comes from the Building and Manufacturing and Service Sectors (accounting for the 66% of the total monetary income). However, if we compare the monetary income with the equivalent amount of money that is obtained from the subsistence agriculture, we find that the agriculture still stands as the biggest form of income generation for the community. When we look at the intensive variable, it shows us that the production per hour of work for agriculture is 0.118 $/hour, which is lower when compared with the rest of sectors that have an average of 0.164 $/hr. This is a common feature all along the world, the agriculture cannot compete with the rest of sectors in terms of productivity per labor invested. Even though, the low level of economic development in Laos explains that the differences in the intensity of the monetary flows per hour in agriculture and the non-agricultural sector is still very small, if compared with the gradients found in industrialized countries.

2.5. The last scaling-up to the level of the national economy: acknowledging the difference between the analysis of urban and rural metabolism

As discussed in Part 1, there is a clear incompatibility in the definition of the identity (scale and lexicon) of the descriptive domain required to represent the urban metabolic pattern and the rural metabolic pattern. As illustrated in the example of Catalonia in Figure 7, the density and intensity of the flows can be order of magnitude different in the two cases. This is an important point, since we have to be able to have a good understanding of the two metabolic patterns associated with socio-economic systems. When we focus on those categories of human activities affecting land uses (agriculture, forestry, residential) we tend to miss the vast majority of the activities generating added value. The reverse is true if we only focus on economic growth, a lot of crucial environmental process will be simply ignored.

The terms of this dilemma are illustrated with the data we gathered in our case study of Laos in Figure 21. We can see that when considering the profile of land allocation between rural Laos and urban Laos (graph on the left) only the 0.09% of the land of Laos is included in the category Urban. However, if we look at the graph on the right we find out that, in spite of this negligible fraction, more than 60% of the GDP of Laos is generated in Urban areas. Please notice that the capital city – Vientiane – is everything but a large metropolitan area (it has a population of around 200,000 people!).

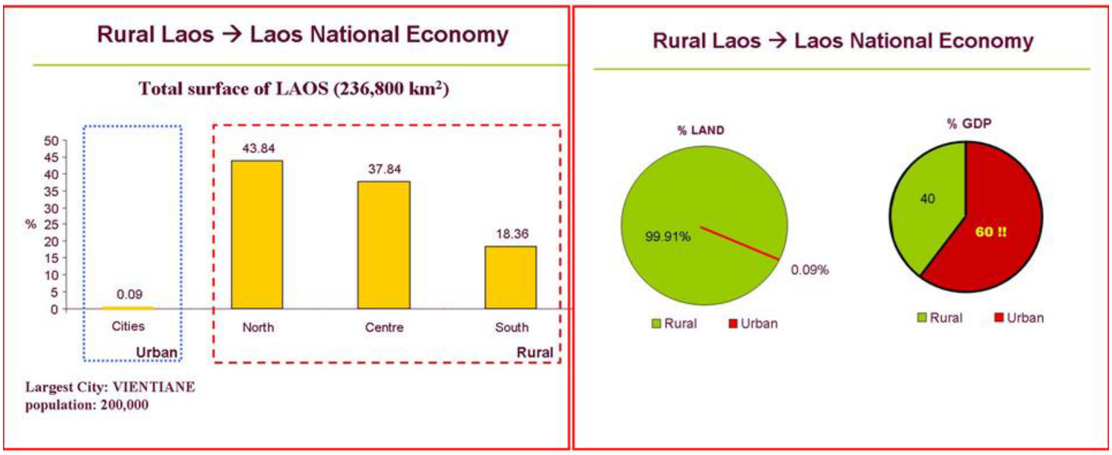

Figure 21: The non-linearity in the profile of land uses and in the profile of relative flows when considering the urban versus the rural metabolic pattern in Laos

It is important to visualize this incredible gap in the characteristics of the Urban and Rural metabolism. In fact, if one is concerned with a quick economic growth of the country, we have to conclude that everything relevant, in relation to this goal, is happening only in urban areas. On the other hand, when dealing only with the maximization of GDP, in a case like Laos, not only we will miss completely the ecological view (a large fraction of the land in Laos does not produce hardly any monetary flow), but also the perspective of a large fraction of Laotian rural people, that is still living outside of a full market economy. Again the MuSIASEM approach does not claim or can provide an indication in normative term. That is, it does not indicate the best development policy that should be followed. However, what the MuSIASEM approach can do is to help an informed discussion and fare deliberation over possible development choices. This discussion can be done on scenarios which can be characterized using integrated packages of indicators, reflecting an integrated characterization of performance in relation to different hierarchical levels, different geographic locations and different dimensions of analysis. In relation to this task, we believe that this case study backs up the claim that the MuSIASEM approach seems to be a promising tool.

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