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INFORMAL SETTLEMENTS AS SOCIO-ECOLOGICAL SYSTEMS: THE METABOLIC PATTERN OF THE VIDIGAL SLUM IN RIO DE JANEIRO, BRAZIL

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Informal settlements, Metabolic Pattern, Socio-Ecological Systems, Rio de Janeiro, Brazil

ABSTRACT

This paper presents the preliminary results of a study aimed at characterizing the metabolic pattern of informal settlements (slums) in order to understand the factors affecting their interaction with the rest of the urban context and the material standard of life of their population. The study applies an innovative approach – the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism – integrating socio-economic and spatial data. The preliminary results presented include: (i) a taxonomy of categories of accounting characterizing the set of activities carried out by the residents (to which one can associate assessments of flows per hour); (ii) a taxonomy of categories of accounting of land uses characterizing the set of spatial elements making up the slum (to which one can associate assessments of flows per hectare); (iii) a set of parameters making it possible to link assessments of flows (food, energy, water, waste and money) per hour and per hectare; (iv) an analysis of the interaction of the slum with the rest of the Rio de Janeiro in terms of job commuting. The conclusion indicates directions for future research.

INTRODUCTION

Informal settlements, slums, or shanty towns, are self-created by the poorest stratum of the population, generally around urban areas. Characterized by the lack of government planning, tenure regulation and public services, they usually are the result of high demographic density, poor transport system and a lack of affordable housing supply.

Slums are very important components of city dynamics, because they provide the dwelling place for a significant share of the urban labour force (UN - Habitat, 2003) and because they contribute to the urban metabolism as consumers of energy and material goods and as generators of wastes. However, in spite of the importance of this type of settlement, it is very difficult to obtain reliable information about their functioning. This makes it difficult to design and implement effective policies to deal with the problems of slums. Many governmental and non-governmental programs have the goal to improve living conditions within slums, but the efforts of these programs are often hampered by a lack of a systemic understanding of this important urban phenomenon.

This paper aims at studying the metabolic pattern of Brazilian slums from an internal perspective: by identifying the factors determining the material standard of living as perceived by the slum's dwellers and workers. This neglected view is important for two reasons: (i) to compare the representation of the problems of slums currently in use for defining public policies and non-governmental programs with the perception of the problems of the slum dwellers themselves; and (ii) to understand the drivers shaping the dramatic development of slums all over the world. In fact, slums are the first residential solution for those migrating to the cities, the type of dwelling most rapidly growing on our planet. Traditional cities, already well defined in their structural and functional characteristics can be considered as *frozen typologies of urban metabolic patterns*. On the contrary slums represent tentative and transitional solutions to the residential problems of their

dwellers, and hence are *flexible and evolving typologies of urban metabolic patterns* that can be improved and tailored to the specific characteristics of the context. However, in order to be able to do so, it is important to obtain a robust representation of their functioning and problematic through discussion with and agreed upon by the local inhabitants.
For this purpose we adopt a methodological framework –the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM)– that considers informal settlements as a special case of Socio-Ecological Systems. The resulting characterization individuates a set of flows metabolized by the slum (e.g. food, energy, water, money) that are associated to a set of funds (e.g. hours of human activity counted in different categories, square meters of residential structures counted in different categories). After having associated flows to fund elements, the method tracks the sources of the flows that are consumed and the sinks of the flows that are discarded. Essential in this analysis is the assessment of the level of openness of the system, defining how much and where flows and funds cross the boundary between the system and its context. In this paper we present the preliminary results of the development of a system of accounting for characterizing the metabolic pattern of the Vidigal slum in Rio de Janeiro, Brazil.

Informal settlements (slums)

Nowadays, about 830 million people live in slums worldwide. By 2030, about 3 billion people, or about 40 per cent of the world's population, will need proper housing and access to basic infrastructure and services such as water and sanitation systems. In some cities, up to 80 per cent of the population lives in slums and fifty-five million new slum dwellers have been added to the global population since 2000. Sub-Saharan Africa has a slum population of 199.5 million, South Asia 190.7 million, East Asia 189.6 million, Latin America and the Caribbean 110.7 million, Southeast Asia 88.9 million, West Asia 35 million and North Africa 11.8 million (UN - Habitat, 2003).
According to the United Nations, slums are sites with one or more of the following items:

- Lack of basis services – sanitation, safe water, waste collection, water, roads, etc.
- Unhealthy living conditions and hazardous locations (usually related to the lack of services)
- Poor structural quality of housing
- Overcrowding
- Insecure residential status – lack of formal documents of tenure

The United Nations (UN - Habitat, 2003) suggests four different methods to define a slum area:

- Geographic Information System – it is possible to overlap different maps (shapefiles) of indicators, specifying areas where there are simultaneously concentrations of indicators, according to the analysis desired, e.g. areas having the bottom 20% of values for different indicators.
- Instrumental or Proxy Variables – analysis for the combination effect of different dimensions throught a single variable, e.g. the US$1 a day as a measure of poverty.
- Indices or multidimensional methods – elaboration of an index using weighted linear combinations of the different variables, e.g. the human development index (HDI) or the city development index (CDI).
- Multi-criteria approaches – association of a place or area with features normally found in slums. The advantage of this approach is that it deals with the analysis of the characteristics of households (more relevant to discuss improvement in material standard of living).

The Brazilian Institute of Geography and Statistics (IBGE) defines a slum as a place with 51 or more housing units, absence of tenure and at least on of the following chacacteristics: irregularity of traffic routes and/or of the size and shape of the house area and/or; lack of essential public services (such as garbage collection, sewage system, water supply , electricity and public lighting (IBGE, 2010). In Brazil, about 11.42 million peoples live under these conditions, of whom 59,3% are located in the metropolitan regions of São Paulo, Rio de Janeiro, Belém, Salvador and Recife. According to Data Favela, the almost 2 million people who live in slums in Rio de Janeiro transact 12,3 billion Brazilian Real a year. Throughout Brazil, slums transactions surpass 64 billionBrazilian Real in a year.

Rio de Janeiro and the Vidigal Slum

Slum development in Rio de Janeiro have appeared throughout the city since the 1940s. Given the local topography full of mountains along its extension, Rio de Janeiro´s slums are often located on hilly sites and are primarily located in the suburbs, where there is an inneficient public services supply, such as transportation, education, health and security conditions are precaurius, as well as environmental conditions are poor. Nevertheless, a hallmark aspect of some slums is its proximity to the most valuable neighborhoods in town[1], highlighting the social inequality. This is the case of Vidigal located in southern zone of the city, between Leblon, Gavea and São Conrado neighbourhoods. Historically, the central and southern zones of the city are where middle and upper income households reside (Cavallieri & Vial, 2012; Oliveira et al., 2012; Pamuk & Cavallieri, 1998). About 174 thousand people lived in slums on the southern area (17% of southern population) in 2010. By far Rocinha is the biggest one, with a population of 69 thousand people, which gives this slum the title of being one of the largest in Latin America. In the same period, the population of Vidigal counted 9,679 persons living in 3,235 dwellings.

MULTI-SCALE INTEGRATED ANALYSIS OF SOCIETAL AND ECOSYSTEM METABOLISM

Multi-scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) is an approach to sustainability quantitative assessments that integrates distinct models for different dimensions and scales of analysis (Giampietro et al. 2012; 2014). Originally developed to address multi-scale issues regarding sustainability of rural systems (Serrano-Tovar and Giampietro, 2013), MuSIASEM has been then applied to the analysis of urban developed and developing economies. MuSIASEM's foundations lay on theoretical concepts developed in the field of complex systems analysis (e.g. autopoiesis, holon, hierarchy) and from theoretical ecology (e.g. metabolic pattern), while for the quantitative analysis it makes use of Georgescu-Roegen's fund-flow model (Giampietro et al. 2012). This combination makes it possible to integrate economic, social, demographic, and environmental variables in the analysis of the metabolic pattern of society, even though these variables belong to distinct descriptive domains and refer to different hierarchical scales (Giampietro et al., 2012). Hence, the accounting method of MuSIASEM constituting an innovative approach to quantitative analysis that can be employed either for diagnostic or scenario simulation purposes (Giampietro et al., 2014). The procedure comprises five steps, which are presented in Box 1 (Steps 4 and 5 refer to the simulation mode).

Box 1: The five steps of MuSIASEM accounting procedure

Step 1	Defining what the system is in terms of fund elements
Step 2	Defining what the system does in terms of flow elements
Step 3	Generation of the multi-level, multi-dimensional representation of the metabolic pattern
Step 4	Checking the viability and desirability domain of the metabolic pattern—intern constraints
Step 5	Checking the feasibility domain of the metabolic pattern—external constraints

According to Georgescu-Roegen's fund-flow model: (i) flows are either inputs (e.g., food, energy and mineral inputs) or wastes (e.g., garbage, GHG and other pollutants) of the systems that either appear or disappear during the duration of the analysis; (ii) fund elements represent the structural elements (e.g., human beings, spatial structures, technology) that compose the functional compartments of the system and maintain their identity (Giampietro et al., 2014).

[1] Slums located in high household income areas have escaped the ''clean up'' of the 1960s and early 1970s. At that time, the government tried to remove much of the slums, and, indeed, some have been removed. The Vidigal began to be occupied in the 1940´s. In the 1970´s there was an attempted eviction of slum, when some residents were moved to a housing complex in western zone. However the dwellers led a movement for permanence and improvement of local infrastructure, thus preventing the complete removal (Oliveira et al., 2012), benefiting from being near to the center of the city, which is still the area that concentrates most jobs of high income.

Application of the MuSIASEM approach to the analysis of urban informal settlements

The example of diagnostic analysis of Vidigal slum is based on secondary data mostly gathered from two sources: (1) the Brazilian Institute of Geography and Statistics (IBGE) - http://www.ibge.gov.br/home/; and (2) statistical data from Pereira Passos Institute - http://www.rio.rj.gov.br/web/ipp.

The first step requires to identify the fund elements of the slum. In a first approximation we decided to include in the analysis of the metabolic pattern of informal settlements only two fund elements: (i) Human Activity (HA) associated with the presence of people and accounted over a finite set of different categories of functional activities; and (ii) Land Uses (LU) associated with a finite set of structural elements occupying space in the slum. Assessments of the hours of HA allocated over the mix of activities expressed by the dwellers and workers in these communities are relevant for the socio-economic dimension. Assessment of square meters of LU allocated by the community in the spatial organization of the slum are relevant for the biophysical and ecological dimension.

Following the procedure implied by the MuSIASEM approach this double, non-equivalent characterization of the chosen fund elements is obtained by defining two dendrograms of splits of the Total Human Activity (the population of the slum multiplied by a time unit) and the Total Land Uses (the total square meter of buildings and other infrastructures) over functional compartments of the slum. In turn, it requires the pre-analytical development of a grammar determining: (i) the taxonomy - the particular lexicon of specific semantic categories to be used in the representation; and (i) the expected relations among them.

The multi-level analysis of the fund "Land Use" in Vidigal

The Land Use analysis refers to two views: (i) land use inside the slum; and (ii) the interface of the slum with its context – Rio de Janeiro. The internal view uses categories making it possible to make the distintion between different types of buildings (residential, non-residential, with a different number of storeys) and different types of no-built up areas. The categories are associated to different types of human activity. The external view identifies the characteristics of Rio de Janeiro that could influence the metabolic pattern of the slum, by affecting the pattern of human activity of the dwellers. This step is crucial tounderstand how city dynamics will impact the slum.

Land Use Inside the Vidigal Slum

The analysis of the fund element "Land Use" requires the use of a Geographic Information System (GIS) in order to produce geo-referenced data. As noted earlier this accounting is essential not only to understand what is going on inside the area of interest but also in its surroundings. In fact, the spatial analysis of flows makes it possible to study interactions of functional elements inside the slums and at the same time the interactions of the slum with its context. In this analysis, the GIS can be used not only to characterize and measure the size of the fund elements (in square meters), but also to identify typologies of structural and functional objects (buildings types, trees, roads and others) via remote sensing. The analysis presented in this study refers to the available information referring to 13 areas defined in Vidigal. The assessments of average residential area by houses and appartments, and commercial by stores and others were obtained from Rio de Janeiro's Low-income settlements system[2].

Key task for this analysis is a pre-analytical definition of a taxonomy of categories of fund elements making it possible to identify the various elements determining the overall area of the investigated systems and to generate a dendrogram of splits. To generate a dendrogram we start by dividing the whole area included in the border of the slum in the two categories of land use: "building" and "non-building". Then we can move to subcategories of these two categories. For example the generic category of "buildings" can be divided in "residential" and "non-residential". Then each one of these sub-categories can be divided in lower level sub-categories. For example, non-residential building can be divided in buildings hosting "economic activities" and "services" – that is where hours of paid work (the fund human activity) and technical capital (a fund non considered in this analysis) are located. Whst is important is to keep closure on the total area (the sum of the area of the lower level categories has to match the area of upper level categories). The dendrogram of land uses generated in this study is illustrated in Fig. 1.

[2] http://portalgeo.rio.rj.gov.br/sabren/index.html

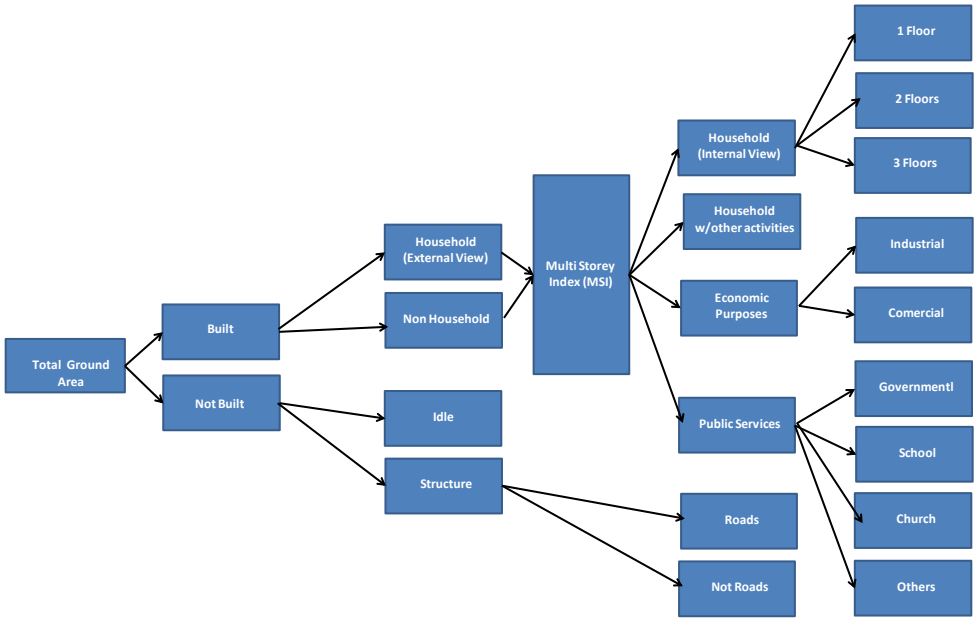

Figure 7 - Dendrogram of splits of land uses over the chosen taxonomy of categories

This system of categorization makes it possible to define the following set of parameters:
*** Inside Residential area Density [m^2HH_{in}/pc]** – square meter per person when considering the area inside the house. It characterize the space available for human activity inside the household, and can be associated to the material and energy flows throughout the study area.
*** Multi Storey Index [m^2BD_{in}/m^2BD_{gr}]** – it is the ratio between the internal area useful for hosting human activities and the total ground area occupied by buildings. This ratio is increased by the number of floors below and above ground. Thus the MSI makes it possible to establish a link between the indoor space available per person (either in residential or commercial buildings) and the external land requirement for building per inhabitant in a given area. This information is essential to assess the density of the flows of input flows and wastes.
*** Residential Fraction [m^2BDR_{gr} (residential)/m^2TBD_{gr} (total building)]** – this ratio indicated the fraction of built ground area that is required by household activities (residential) versus the built ground area dedicated to activities taking place in the Paid Work sector. This distinction is important because the two typologies of building do have a different mix and a different density of metabolized flows.
*** Built-up fraction [m^2TBD_{gr} (total building)/m^2total area]** – represents the density of buildings in a given area, It determines the density of the flows metabolized by the mix of different typologies of buildings
*** Paved fraction [m^2NBA_{pav}/Total m^2NBA]** – indicates the importance of roads, internal courts, parking in relation to parks, trees and other natural covers. A large fraction of paved area over the non built area can mean better transportation of people, as well as better waste disposal.

Using these parameters it become possible to establish a link between data referring to metabolic rate per hour (how much food, energy, water, waste is generated per hour of activity of a person) to data referring to the metabolic density per square meter of the slum (how much food, energy, water, waste is generated by the slum as a whole).

Vidigal in the City Context

The concept of socio-ecological systems can be used to define three criteria of sustainability by considering that the metabolic pattern required for reproducing the funds making up the structural elements of societies has to be: (i) feasible in biophysical terms – compatible with natural processes outside human control; (ii) viable in biophysical and economic terms – compatible with technical and economic processes under human control; and (iii) desirable in normative terms – respecting the aspirations and the values of the people living in it (Giampietro et al. 2014). These three criteria can be checked by analyzing the pace of the metabolism of the different flows per hour of human

activity (in the different categories) and the density of the metabolism of the different flows per squeare meter of land uses and land covers (in the different categories).
More specifically, a sustainable urban metabolism should not damage the ecological processes taking place in the surrounding ecosystems (feasibility in relation to the environment) and should be capable of stabilizing the flow of inputs (food, energy, water and materials) required to sustain the life of urban dwellers. An effective analysis of the metabolic pattern has to address in an integrated way the implications of several issues such as: demography, economy, human health, mobility/accessibility, equity, community strenght, efficacy of policies and regulations, employment, and education (Pincetl et al., 2012).
For this reason, it is essential to include in the analysis of the metabolic pattern the factors determined by processes taking place in the area surrounding the slum (the rest of the city), since they directly influence the lives of dwellers. As described below the key link between Vidigal and Rio de Janeiro has to do with: (i) work commitments – a large part of the dwellers get its income working outside the slum; and (ii) goods and services coming from the rest of the city – the vast majority of the goods comes from the rest of the city, whereas the level of services delivered to the slum by the rest of Rio de Janeiro is totally unsatisfactory. This fact points at the importance of including in the metabolic analysis of the slum also the economy activities, since they have a direct impact on dwellers and the analysis of the movement of the dwellers throughout the city in order to assess the time spent for commuting to work. Measuring the time lost commuting to and from work give important information on the level of monetary income per hour of time spent in working (when considering the actual work and the commuting).

The multi-level analysis of the fund Human Activity in Vidigal

As done for the multi-level analysis of the profile of allocation of the fund element "land use" we have to characterize a dendrogram of splits of "human activity" starting from the total amount of the fund human activity (total population defined for the whole system – at the level n – multiplied by the hours in a year – 8,760). This amount of hours have to split over the chosen taxonomy of categories of human activities defined at lower hierarchical levels (at the levels n-i). The result of this operation is shown in Fig. 2.

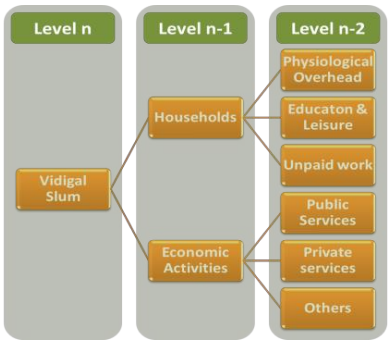

Figure 8 - Dendrogram of Human Activity

The hours of human activity included in households' functional compartment (HH) of Vidigal slum comprises all hours of activity of the dependent population plus the physiological overhead of the working population (= the hours of activity of the workforce when outside paidwork or carring out unpaid work). The functional compartment of economic activities (EA) encompasses mainly services. In fact, manufacturing activities are not significant in the community (Fig. 3b). The human activity in this functional compartment represents only 10% of paid work activities of Vidigal dwellers (Fig. 3a). This clearly indicates that the majority of jobs are outside the slum – mainly in the construction industry and housework in Rio de Janeiro.

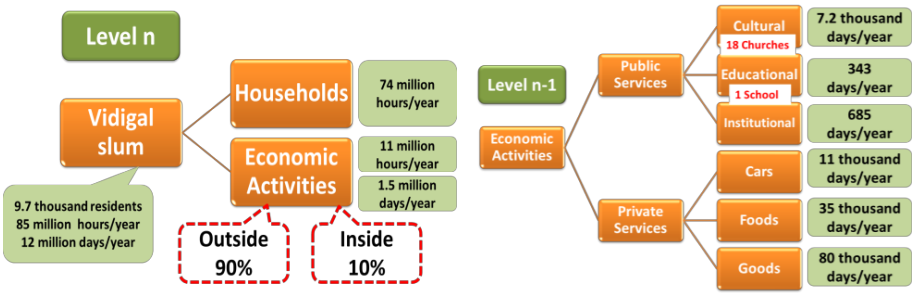

Figure 9 - a) Total human activity (THA) of Vidigal slum and its distribution over level (n-1) functional compartments. b) Human activity of functional compartment EA. (Reference workload: 7h/day)

These numbers suggest that, in terms of energy consumption, besides the electricity getting into household appliances' use, the fuels associated with the commuting may be a relevant aspect, considering that 90% of Vidigal dwellers work outside the slum and Rio de Janeiro's and commute using public transportation relying on fossil fuels. Looking at the category "Public Services" (Fig. 3b), it is worth noting that the slum houses 18 churches (based on working hours guaranteed mainly by local workers, often on voluntary basis) against only one school (requiring the inflow of workers coming from the rest of the city). Although recent studies are not conclusive on cause-effect relationships between religion and poverty, they argue that prosperity leads to decline of religion's relevance. Also, they state that religion becomes more popular when people are anxious and/or insecure about their daily lives, so that the number of religious institutions in a community may be a potential indicator of its life quality standards (Paul, 2009; Gilani et al., 2012; Ross, 2013). Finally, the analysis of work and economic activities in slums implies addressing the issue of illegal and criminal activities, for which Brazilian slums are very famous. The assessments referring to these activities should be included in the functional compartment "Private Services" (for the moment they are still to be quantified).

RESULTS AND DISCUSSION

The Land Use metabolism inside the slum

As stated before, the Vidigal is divided in 13 different areas in the most disaggregated census we could achieve.

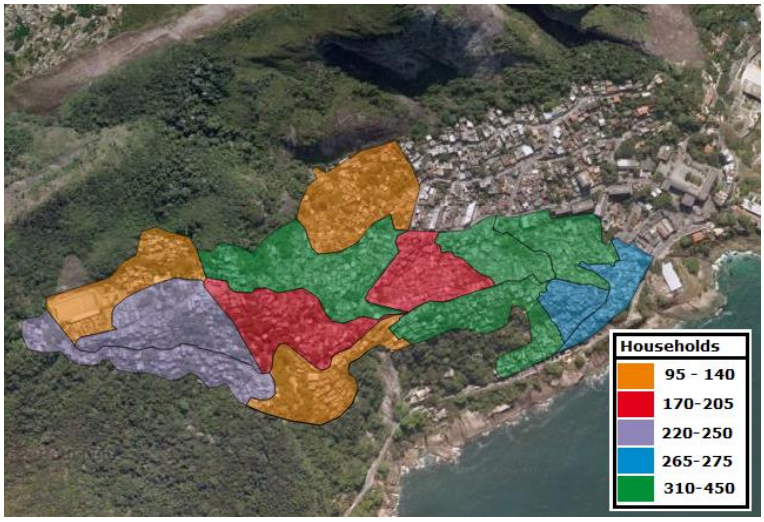

Figure 8 – The 13 Vidigal areas characterized by density of households

We calculated for these 13 areas (labeled from A to M) an analysis based on the set of parameters described in Section 2.2.1.
The areas A, B, C and F have the highest concentration of commerce (**Error! Reference source not found.**). The difference between the first and second graph is the consideration of the difference between the area used per person when considering the external view (square meter of ground are occupied by buildings) and the internal view (square meter used by people inside the building). This difference depends on the Multi Storey Index. For example, the area "C" have a 50/50 ratio over the area households and non-households when considering the ground area, but the concentration of buildings with two or more floors in this area results in 87% of land use for housing because of the larger value of the Multi-Storey Index[3].
Another important issue is the relation between built area and non built area. This could be specially important for health, environmental and transportation issues. The Brazilian Institute of Geography and Statistics often differs slums based on caracteristics such as spacing between houses, floors and displacement within the favela. A very common feature in slums is the very narrow width of the streets. This especially applies to roads where cars or motorcycles do not pass (peatonal). Given the width of the alley, many areas do not have a good air circulation and have no incidence of sun. This combination is dangerous for diseases, especially tuberculosis. The Rocinha slum (a Vidigal neighborhood) has one of greatest tuberculosis incidence rates in the state. The existence of trees is also important for health, and is good for the environment

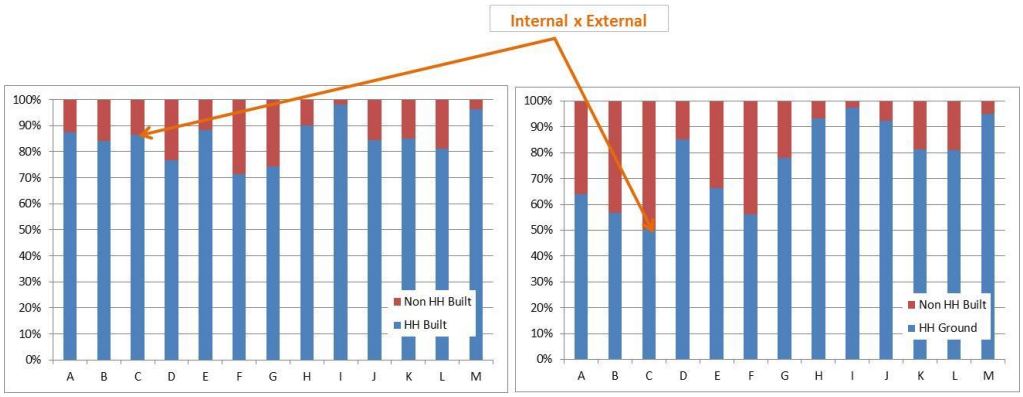

Figure 11 - Household and Non Household Land Use

An interesting observation is the relationship between the size of streets and commerce (e.g. areas A, B and C). Most of commerce is located in the main street of the slum, where access via automobile is better, allowing entry and exit of goods, as well as the higher circulation of people (**Error! Reference source not found.**). Therefore, a large fraction of paved area over the non built area can also mean better transportation of people, as well as better waste disposal. Poor waste disposal may impact population's health and water bodies.

[3] Assuming that all commercial facilities are on the ground

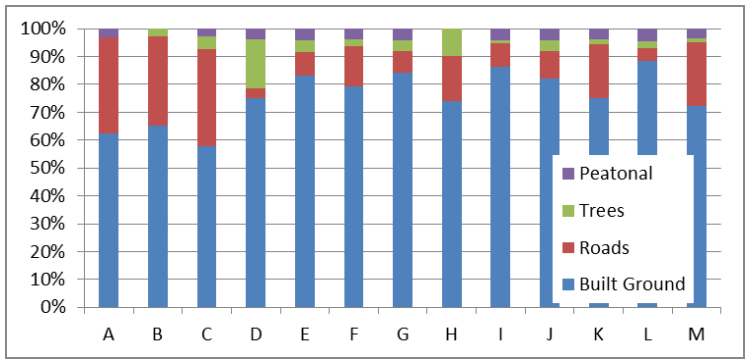

Figure 12 - Built and Non built Land Use

The land use decomposition among buildings (built up) allows the user to identify areas with specific public or private services. By the economic purposes sector all utilities are private services, such as bars, car maintenance and banks. The public services represents education, health and governments facilities. The difference between the two graphs shown in **Error! Reference source not found.** reflects the two sets of assessment referring to the external and internal view discussed previously and depending on differences in Multi-Storey Index.

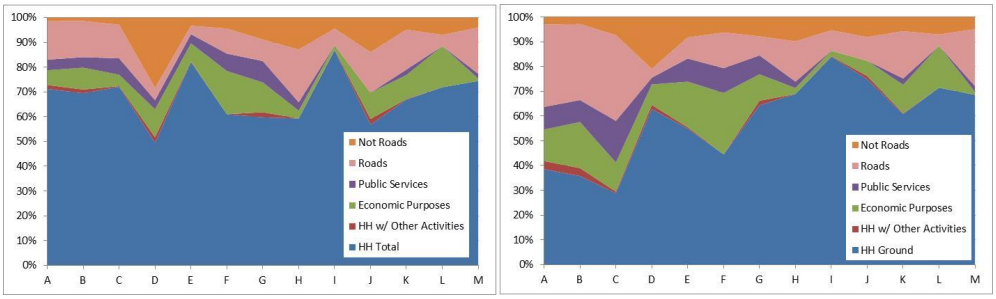

Figure 9 - Land use by building typology and the presence of roads, divided by: left graph) HH Total and right graph): HH ground

Another issue regarding the sector is the existence of a few household with other activities, mainly in areas A, B and C. This uits are homes with residents in autonomous work, such as a seamstress and confectionery, probably not regulated by the government, thus not paying taxes. The density of buildings or, afterall, HH or commerce unit spaces determines the density of flows metabolized.
The multi-storey index represents the density population along a region, there it is also a good proxy for human activity density availability, done throught a proxy for the floors average. The index can be dfined as the ratio internal area useful for hosting human activities and the total ground area occupied by buildings. For example, the household land use is slightly less than 30% considering land use on the ground for the “C” area (externl view), but it is greater than 70% in the same area when considering the Multi-Storey Index. Areas with a great population density also would need a more robust and efficient transport service. This areas are also where the local government shoul install public services.

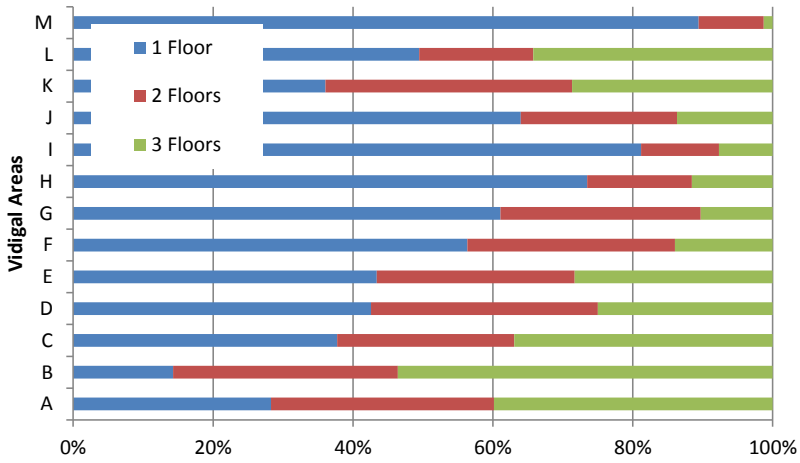

Figure 10 - Multi Storey Index

The final land use decomposition, normalized per hectare of land, is illustrated in Figure **11**.

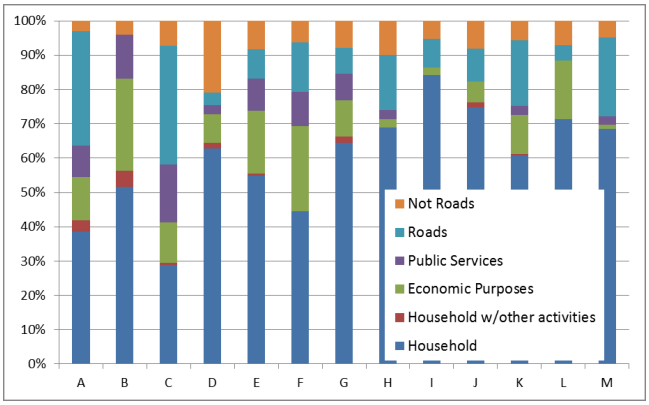

Figure 11 - Land use decomposition by hectare

The Urban Metabolism Outside the Slum

The Human Activity and the City Transport

Since the majority of dwellers' jobs is outside the slum, the inhabitants of the slums must rely on the public city transport system every day. Therefore, the time spent in commuting is an important factor determining their life styles. Spatial analysis allows the contextualization of vidigal related to actors around - mainly in the southern part of the city - allowing a better understanding of its socially and economically dynamics. The main economy sectors referring to jobs taking place in Vidigal are indicated in Table 9. They include: Educational Facilities, Rubber and Leather Industry, Credit Insurance and Real Estate[4], Metallurgical Industry and Public. Their geographic location in the city is illustrated in the figure.
In 2013 Vidigal dwellers had an income of about 3.5 million Brazilian Real (a 42% increase compared with the year 2010). In 2010 the average income coming from these sectors of a household was 1,744 Brazlian Real (IBGE, 2010) when considering that a fraction of the 9,600 inhabitants is unemployed or does not work in any of these sectors. For comparison, the average income for Rocinha and Complexo da Maré in the same year was about 1,290 Brazilian Real.

[4] Sum of the real estate and Credit and Insurance and Capitalization sectors.

Moving to a spatial analysis, we can say that most of commercial activities are located in areas with good transport service. This applies to small commercial activities located on the main streets of Vidigal, as well as for some important industries in Rio de Janeiro. In both cases, the need for a good transportation is essential for an easy access of the customer, but also for the arrival and departure of products and workers. Thus, areas of industry concentration needs a transportation network of large capacity.

Table 9 - Total Wages (R$ - Brazilian REAL)* by Economic Acivity - Vidigal

Economy Sector	**2010**	**2012**	**2013**
Housing, Food and Maintenance	1,554,221.76	1 783 791.46	2,126,406.88
Real Estate	367,865.55	654 444.00	694,399.17
Credit, Insurance and Capitalization	352,898.70	436 662.16	328,009.76
Retail Business	67,574.64	100 751.93	151,012.40
Industrial Service for Public Utilities	47,967.04	61 584.71	68,548.80
Rubber and Leather Industry	-	-	57,420.44
Transport and Comunication	43,756.51	36 158.76	30,352.59
Education	-	1 178.57	13,432.14
Food, Beverages and Alcohol industry	5,235.30	8 221.50	6,907.18
Metallurgical Industry	2,200.31	2 555.94	5,470.76
Wholesale Trade	7,595.52	3 465.00	4,953.72
Civil Construction	-	9 798.00	2,475.00
Medical services	1,351.44	-	-
Total (R$)	**2,450,660.94**	**3,098,609.85**	**3,489,389.82**

* - Result of the average nominal income of employees in December (2010, 2012 and 2013) times the number of jobs in each year.
Source: Ministry of labor and Employment (MTE), Brazil

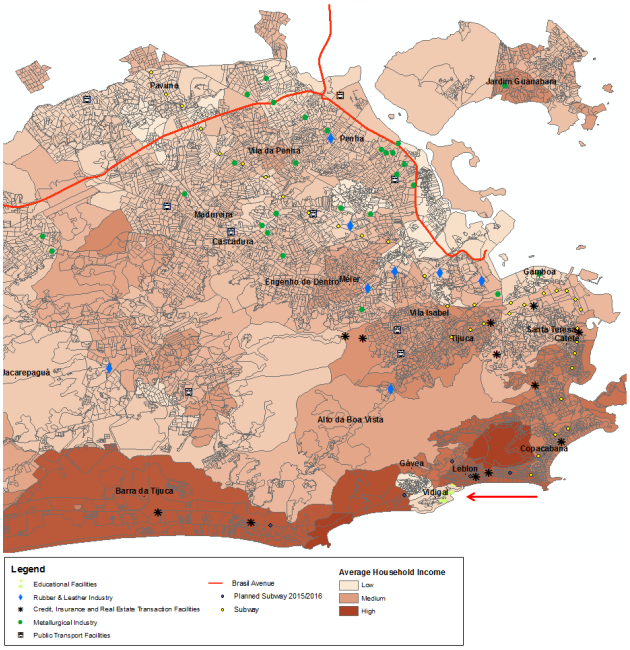

Figure 12 - Rio de Janeiro´s Average Houseold Income by neighborhoods (2010) and Geographical Location of Specific Economy Sectors Units. Source: Own Development

There is no service of public transportation into Vidigal, so the dwellers depends on the local service of motorcycle taxis and kombis to go up and down the slum. In 2010, there were only two bus lines operating from the slum entrance. According, to a survey conducted along some dwellers, the public transportation is the second worst problem for the people living in the slum (Oliveira et al., 2012). The steady increase in the number of vehicles circulating in urban centers, mainly private cars with low transport capacity, has generated serious problems as excessive pollution and congestion. This reflects a preference given to road transport system in Rio de Janeiro, rather than other transport modes as the rail system.

A list of the required travel time from Vidigal to potential working location is given in Table 10. These estimates refer to one-way trips made throught public transport (mainly bus). It should be noted the possible great time lost by residents of Vidigal on commute, because a poors bus network and vehicle traffic. Furthermore, it should be highlighted that a travel from Vidigal to the Centro, which lasts 1:28h by bus, would last 0:35h by a prvate car. This implies that there is no incentive to use public transport for those that have the option of using a car. A fact that primes a chain reaction where more cars are purchased further worsening the city traffic[5]. Considering the worst case[6], a single person may waste about 1300 hours (out of 8760 hours/year) on commuting. On a macroeconomic perspective, residents who have big losses of time commuting will contribute less to the total human activity in the whole econmy. A poor transport structure brings losses to the city's economy.

Table 10 – Travel time* from Vidigal to the selected work areas

Journey	**Monday (12h)**	**Monday (19h)**	**Sunday (23h)**
Vidigal – Leblon	0:22h	0:22h	0:15h
Vidigal - Centro	1:10h	1:28h	1:30h
Vidigal – Vila Isabel	1:40h	1:35h	1:40h
Vidigal – Ilha do Fundão	1:35h	1:50h	2:00h

[5] This situation is even worsened, when the Brazilian government reduces taxes and rates related to the car industry through measures to boost the economy.
[6] Considering 256 working days

Vidigal - Penha	2:20h	2:30h	2:30h
Vidigal – Jardim Guanabara	2:25h	2:30h	2:50h
Vidigal - Pavuna	2:15h	2:25h	3:00h

* journey´s duration were collected via google maps

The Human Activity in the Context of Slums

The relation between the slum and the city includes relevant aspects beyonds purely economic issues. A very common work position in Brazil that probably is not considered in Table 9 is the domestic service. Given the proximity of Vidigal to very high income neighborhood (dark red on the map in Fig. 19) – 20 minutes by bus and depending of the region could be about 10 minutes by walk - this is where most probably much of the hours of Vidigal paid work is allocated. This situation represents a very common situation, mainly in developing countries, where many poor dwellers work ensures that the needs of rich and other higher income groups are met.

The analysis of the role of human activity in the stabilization of the metabolic pattern of both rich and poor households can be very useful to realize others entrails of a society. In fact, the urban sustainable metabolism should not focus only on the economic capital but also on cultural capital - that has to do with the education and the experience done by the various citizens from the first years of life. This point is particular important because poor people do not have access to economic resources that would be required to develop their cultural or social capital, because they are forced to work, already when child, to help their families (Souza, 2013).

CONCLUSIONS AND FURTHER RESEARCH

This paper present preliminary results of a study carried out within the activities of a EU sponsored project: *NETEP*–European-Brazilian Network on Energy Planning. It illustrates the initial steps required to apply the MuSIASEM approach to the analysis of urban informal settlements. This preliminary results indicates the possibility to analyze the metabolic pattern in relation to both the activities taking place inside the slum and the commuting routines of its dwellers. By generating a proper system of accounting it becomes possible to describe the functioning of the slums using variables and narratives that are relevant for the dwellers (since they reflect their problems and their perception of "improvements") and integrate these variables and narratives with those relevant for the urban elites deciding policies and regulations about the slums.

In scientific terms the challenge is to develop specific grammars for the accounting that characterize system's funds in a way that is relevant. In relation to this point the MuSIASEM approach has been developed to be implemented using participatory process, involving the slum dwellers and other stakeholders. In the next phase of this research we will gather stakeholders's contribution in order to map in a more robust form the flows of food, energy, water, waste (against monetary flows) associated with the different categories of human activity. Participatory process should also provide a more robust information about the problems experienced with commuting. A progressive integration of the slums into the fabric of the rest of the city will requir transportation policies for high capacity public transportation preventing a further increase in the use of cars. Slum policies should study how to increase the capacity of income generation by ensuring easy access to jobs through pro-poor transport and lowincome settlement location policies.

Two additional long terms goals of this line of research include: (i) a comparative analysis of the metabolic pattern of informal settlements – looking at the inner and outer diversity – across different areas of the world. We are already trying to compare the benchmarks found for Vidigal with the benchmarks characterizing the metabolic pattern of a slum around Cape Town in South Africa; (ii) a more detailed analysis of the importance of criminal activities – i.e. drugs trafficking – in the stabilization of the metabolic pattern when looking at monetary flows.

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