Technology
Arts Sciences
TH Köln

UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

FACULTADES DE CIENCIAS QUÍMICAS, INGENIERÍA Y MEDICINA

PROGRAMAS MULTIDISCIPLINARIOS DE POSGRADO EN CIENCIAS AMBIENTALES

AND

TH KÖLN - UNIVERSITY OF APPLIED SCIENCES

INSTITUTE FOR TECHNOLOGY AND RESOURCES MANAGEMENT IN THE TROPICS AND SUBTROPICS

EVALUATION OF FOOD FLOW: URBAN METABOLISM IN THE NORTHWEST OF RIO DE JANEIRO STATE, BRAZIL

THESIS TO OBTAIN THE DEGREE OF

MAESTRÍA EN CIENCIAS AMBIENTALES

DEGREE AWARDED BY UNIVERSIDAD AUTÓNOMA DE SAN LUIS POTOSÍ

AND

MASTER OF SCIENCE

NATURAL RESOURCES MANAGEMENT AND DEVELOPMENT

DEGREE AWARDED BY TH KÖLN – UNIVERSITY OF APPLIED SCIENCES

PRESENTS:

DAIANA M. CASTILLO LOPEZ

CO-DIRECTOR OF THESIS PMPCA

PROF. DR. PEDRO MEDELLIN MILAN

CO-DIRECTOR OF THESIS ITT

PROF. DR. JOHANNES HAMHABER

ASSESSOR:

PROF. DRA. SABINE SCHLÜTER

COLOGNE, GERMANY DATE: AUGUST 14th, 2018

PROYECTO FINANCIADO POR:

DEUTSCHER AKADEMISCHER AUSTAUSCH DIENTS – DAAD
GERMAN ACADEMIC EXCHANGE SERVICE
FUNDING PROGRAM: DEVELOPMENT – RELATED POSTGRADUATE COURSES 2016
COD: 57252259

PROYECTO REALIZADO EN:

ITT
TH KÖLN – UNIVERSITY OF APPLIED SCIENCES

CON EL APOYO DE:

DEUTSCHER AKADEMISCHER AUSTAUSCH DIENST (DAAD)

LA MAESTRÍA EN CIENCIAS AMBIENTALES RECIBE APOYO A TRAVÉS DEL PROGRAMA NACIONAL DE POSGRADOS (PNPC - CONACYT)

Technology
Arts Sciences
TH Köln

Erklärung / ***Declaración***

Name / *Nombre*: Daiana M. Castillo López
Matrikel-Nr. / *N° de matricula*: 11117381 **(TH Köln),** 269384 **(UASLP)**

Ich versichere wahrheitsgemäß, dass ich die vorliegende Masterarbeit selbstständig verfasst und keine anderen als die von mir angegebenen Quellen und Hilfsmittel benutzt habe. Alle Stellen, die wörtlich oder sinngemäß aus veröffentlichten und nicht veröffentlichten Schriften entnommen sind, sind als solche kenntlich gemacht.
Aseguro que yo redacté la presente tesis de maestría independientemente y no use referencias ni medios auxiliares a parte de los indicados. Todas las partes, que están referidas a escritos o a textos publicados o no publicados son reconocidas como tales.

Die Arbeit ist in gleicher oder ähnlicher Form noch nicht als Prüfungsarbeit eingereicht worden.
Hasta la fecha, un trabajo como éste o similar no ha sido entregado como trabajo de tesis.

Köln /San Luis Potosí, den /*el* 14.08.2018
Unterschrift / *Firma*: Daiana M. Castillo López

Ich erkläre mich mit einer späteren Veröffentlichung meiner Masterarbeit sowohl auszugsweise, als auch Gesamtwerk in der Institutsreihe oder zu Darstellungszwecken im Rahmen der Öffentlichkeitsarbeit des Institutes einverstanden.
Estoy de acuerdo con una publicación posterior de mi tesis de maestría en forma completa o parcial por las instituciones con la intención de exponerlos en el contexto del trabajo investigación de las mismas.

Unterschrift / Firma: Daiana M. Castillo López

EVALUATION OF FOOD FLOW: URBAN METABOLISM IN THE NORTHWEST OF RIO DE JANEIRO STATE, BRAZIL

A master thesis prepared by

Daiana M. Castillo López

Supported by

German Academic Exchange Service DAAD

Universidad Autónoma de San Luis Potosí

TH- Köln University of Applied Sciences

EMATER Rio de Janeiro

EMATER office in Itaocara

RioRural Program

Mercado produtor de Ponto Pregunta CEASA – Itaocara

Cooperativa de Leite CAPIL – Itaocara

Associations of small producers from Itaocara

2018

…A las generaciones pasadas y presentes que han mantenido firme la idea que el desarrollo sustentable, la conservación de la naturaleza y la calidad de vida de los pueblos en un mundo mejor para las generaciones futuras, si es posible.

…A todas las tonalidades de verde del altiplano cundiboyacence, a los atardeceres de las planicies llaneras, a las gotas de agua del pacifico, a cada una de las especies del amazonas y al mar de los siete colores de mi tierra colombiana.

ACKNOWLEDGEMENT

This thesis work is the result of the effort and support from:

My family, Candelaria Lopéz, Jorge Castillo, Andres and Cristian Castillo López, aunts, uncles, and cousins in Colombia.

DAAD German Academic Exchange Service

Teachers and directors of this work: Dr. Johannes Hamhaber, Dr. Pedro Medellín, Dra. Sabine Shlüter and teachers at PMPCA and ITT, especially Dr. Antonio Reyes, Mtra. Lucia Nieto and Dra. Elisabeth Huber.

My colleagues and friends ENREM 2016-2018, especially Natalia Muñoz, Marcella Sobisch, David Bossek and Diego Guarín.

My colleagues and friends at the ITT and PMPCA, especially Amalí Abraham and Jose Beleño.

EMATER and RioRural program in Niteroi and Itaocara, especially Dra. Helga Hissa, Matias Silva, Mateus Aguiar, Junior Rangel and Walker Azevedo

Producers and marketers of horticultural and dairy products in Itaocara, especially staff in CAPIL and CEASA.

Community of Itaocara, especially the Macieira family and each of the people in Colombia, Mexico, Germany and Brazil who contributed intellectually, spiritually, physically, emotionally and economically to the development of this work, to whom I will be deeply grateful all my life..

SUMMARY

This study presents an analysis of urban metabolism, particularly for food flows. The purpose of this thesis work is identifying and evaluating the food flows during production, transport, marketing and consumption processes. It given the importance of food security at all geographic scales, taking as study case the Northwestern region of Rio de Janeiro state in Brazil.

For the development of this research work, different analyzes were carried out that allowed the selection of the most coherent methodologies for the fulfillment of the proposed objectives. The selection of the Material Flow Analysis – MFA or graphical and geographical representations through Sankey diagrams and Foodshed Assessment were used. Likewise, the selection of the case study was made through a deeper data analysis.

With regards to the above, this thesis combines two analysis methodologies focused on supporting decision making in cities. These methodologies are the Material Flow Analysis and the Foodshed Assessment. Here, the latter becomes a fundamental tool for the delimitation of boundaries and the scope of former, resulting into complementary analysis methodologies, that strengthen the identification of the energy and matter flows.

In the analysis and discussion chapter, food waste is identified as critical point, especially in the marketing and transportation processes. Similarly, the consumption of energy (diesel) is highlighted as a challenge within the regional food value chain. CEASA Market and CAPIL Association are places also identified as critical points. They have an important role in the whole Food Flow. Finally, the challenges for regional food value chains are presented taking into account the critical points identified during Food Flows analysis.

Key Words: Urban Metabolism, Foodshed Assessment, Material Flow Analysis, Food Security, Food Value Chain

RESUMEN

Este estudio presenta un análisis del metabolismo urbano, particularmente para los flujos de alimentos. El propósito de este trabajo de tesis es identificar y evaluar los flujos de alimentos durante los procesos de producción, transporte, distribución, comercialización y consumo. Lo anterior, dada la importancia de la seguridad alimentaria en todas las escalas geográficas, tomando como caso de estudio la región Noroeste del estado de Río de Janeiro en Brasil.

Para el desarrollo de este trabajo de investigación, se realizaron diferentes análisis que permitieron seleccionar las metodologías más adecuadas con relación a los objetivos propuestos. Se utilizó la selección del Análisis de Flujo de Materiales (Material FLow Analysis-MFA), representaciones gráficas y geográficas como los Diagramas de Sankey y la Evaluación de Cuencas Alimentarias (Foodshed Assessment) para realizar el análisis de los procesos metabólicos dentro del flujo de alimentos. Asimismo, la selección del estudio de caso se realizó a través de un profundo análisis de datos.

Con respecto a lo anterior, esta tesis combina dos metodologías de análisis centradas en apoyar la toma de decisiones en las ciudades. Estas metodologías son el Análisis de Flujo de Materiales y la Evaluación de Cuencas Alimentarias. Ésta última se convierte en una herramienta fundamental para la identificación de los límites y el alcance del Análisis de Flujo de Materiales, lo cual las convierte en metodologías de análisis complementarias, que fortalecen la identificación y evaluación de los flujos de alimentos.

En el capítulo de análisis y discusión, el desperdicio de alimentos se identifica como un punto crítico, especialmente en los procesos de comercialización y transporte. Del mismo modo, el consumo de energía (Diésel) se destaca como un desafío dentro de la cadena de valor alimentaria regional. El Mercado CEASA y la Asociación CAPIL son lugares también identificados como puntos críticos, dado su importante rol dentro del flujo de alimentos. Finalmente, se presentan los desafíos y recomendaciones para la cadena regional de valor alimentara teniendo en cuenta los puntos críticos anteriormente identificados.

Palabras clave: Metabolismo Urbano, Análisis de Flujo de Materiales, Evaluación de Cuencas Alimentarias, Seguridad Alimentaria, Cadena de valor Alimentaria

CONTENT

List of Figures

List of Tables

List of Images

List of Abbreviations

BRL	Brazilian Real (Currency Unit)
CAPIL	Cooperativa de Leite de Itaocara -(Dairy Association)
CEASA	Centrais de abastecimento de alimentos (Trade Point)
CEDAE	Companhia Estadual de Águas e Esgotos
CO_2	Emmision of carbon dioxide
CP	Crop Production
DP	Dairy Production
EA	Emergy Analysis
EMATER	Empresa é responsável pela assistência técnica e extensão rural no Estado do Rio de Janeiro
EMBRAPA	Empresa Brasilera de pesquisa agropecuaria
EUR	Euro
FAO	Food and Agriculture Organization of the United Nations
Gal	Gallon
GDP	Gross Domestic Product
ha	Hectare
HST	Hard Systems Thinking
IBGE	Instituto Brasilero de geografía e estadística
INEA	Instituto estadual de Ambiente
ISO	International Standars Organisation
k	Kilogram
km^2	Square Kilometer
kWh	Kilowatt-hour
L	Liters
LCA	Life Cycle Assessment
m^2	Square meter
m^3	Cubic meter
MFA	Material Flow Analysis
Mm	Milimeters
MP	Meat production
MuSIASEM	Multiscale, multidisciplinary and complex analyses
PAA	Food Purchase Program
PESAGRO	Pesquisa e desenvolvimento tecnológico no segmento agropecuario no estado de Rio de Janeiro
PNAE	National Program of School Feeding
PNFAF	National program to strengthen family farming
RIORURAL	Project - Word Bank
SAN	Segurança Alimentar e Nutricional
SST	Soft Systems Thinking
t	Ton
UM	Urban Metabolism
UN	United Nations

1 Introductory Chapter: Sustainable Cities, Food Flows and Global Environmental Change


Rio de Janeiro city. Photo taken by Borami Moon, 2018

"Our struggle for global sustainability will be won or lost in cities"
Ban-Ki moon

For most people, the city lifestyle could be agitating, stressful and even chaotic, this is mainly due to the number of inhabitants and the urgency to supply their needs. Such has been recorded daily by different newspapers, news, health centres and research institutes (Benedictus, 2014; East, 2016; Lederbogen et al., 2011).

This lifestyle is mainly driven by different energy and resources flows which depend on the needs and purposes of the people who inhabit them. This way, the management, development, quality, quantity, as well as the speed with which these flows are developed, could contribute to increasing or reducing the stress of living in a city.

To understand the function of energy and resource flows in societies, researchers often adopt tools used in the analysis of natural ecosystems for analysis of urban environments (Gragson & Grove, 2006; Pickett et al.,1997), based on understanding the similarities that cities share with ecosystems. (Bodini, Bondavalli, & Allesina, 2012)

With the purpose of understanding cities as ecosystems or to introduce the concept of urban ecosystems, it is necessary first to understand the concept of ecosystem, which can be applied in various dimensions. However, the ecosystem concept developed by Arthur Tansley in 1935 inferred that ecosystems evolve as a result of the reciprocal interaction of the different living organisms with physical factors that form the environment and with energy (E. Odum, 1971). In light of this, Tansley introduces a new line of thought of systems, as more than just the sum of parts or elements that compose it, interacting and relating to each other (Margalef, 2002), which are coherently organized, forming structures which act as a whole and sharing a common function or purpose (Meadows, 2009).

In recent years, city as a concept has been widely studied and discussed from geography, economics, sociology and more recently from ecology; efforts have been important trying to standardize this concept, however, to date it has not been possible to establish a general criterion that defines the concept of city for all countries.

The most important approximations to the city concept have been divided into two criteria, qualitative and quantitative. (Capel, 1975) The latter is often supported by the statistical departments of countries, where the city is defined according to the number of people which compose it with an established geographic area. This approach is based on the population density but has disadvantages when trying to distinguish urban from rural settlements. A typical example would be a concentration of people developing functions related to agriculture or the production of raw materials and resources in rural areas or, in contrast, small agglomerations of people with urban characteristics. In either case, the concept of a city is biased and lost to population density alone.

Owing to the reasons above and for the present work, the concept of a city is established under 3 qualitative criteria. The city as the space where a settlement of people: 1) Concentrates its governmental, economic and industrial activities, as well as the core for the development of transport and public institutions. 2) Depends on the external environment and requires the inputs of energy and resources from the rural areas that surround it and also requires these areas to utilize their outputs. 3) It has a physical structure that allows the development of social, economic and political interrelations

Brazil is a federal republic with 26 federated States and 5,570 urban settlements called municipalities (IBGE, 2016); which for this research are referred to as cities as long as they fulfil the 3 criteria described above.

Building on the concepts of an ecosystem and a city, it is more accurate to introduce the concept of urban ecosystem, which comprises of social, economic and natural factors (Pickett et al., 1997). Zhang et al. 2006, highlighted the characteristics shared between natural ecosystems and urban ecosystems which ranges from material and energy flow analysis characterized by loss of diversity, reduction of trophic chain, and the decline in self-regulation ability. This also includes integration, dependence, vulnerability and resilience (Zhang, Yang, & Li, 2006), a heterogeneous community of living species, (Costa, 2008) as well as accumulation and transformation capacity with regulatory mechanisms (Bai, 2016). This presents the complexity that urban ecosystems can achieve, in addition to ease of modification by the artificial or natural conditions of the environment.

Urban ecosystems are composed of natural and socioeconomic subsystems that are interacting with each other in an open system that allows the exchange of substances, energy and information with the external environment (Zhang, Yang, & Yu, 2008). On acount of this, the natural subsystems that make up the urban ecosystem are based on the physical environmental processes which control and limit the transformation of energy and materials within the same ecosystem. This limits its main function: the transformation of energy (E. Odum, 1971), in addition to the influence of socioeconomic subsystems which allows it to demonstrate the functioning of structures of the whole system (Gragson & Grove, 2006). Hence, when comparing urban ecosystems and natural ecosystems, it is necessary to take into account the function of each of its elements and resilience[1] (Stuart Chapin, Matson, & Vitousek, 2012).

In study of urban ecosystems, the structure of flows and interconnections between elements of a system have been investigated mainly to understand patterns of growth and development of the system. These are two key attributes of sustainability (Bodini et al., 2012) as defined by the World Commission on Environment and Development of the United Nations (WCED) in 1987 where the term sustainability is defined as "a global process of development that minimizes the use of natural resources and reduces its impact on the environment"(WCED, 1987). However, this has become a central research theme during the last 30 years under the paradigm of sustainable cities.

To introduce the concept of sustainable cities, we draw upon the advantages that the organization and structure of cities have for the implementation of sustainability practices (Girardet, 1996). Such includes solid and liquid waste management, policies aimed at efficient use of resources such as water and energy, implementation of renewable energies, as well as control and regulation of emissions by fixed and mobile sources. This also encompasses the concentration of institutions, ease and flow of information, communication and transport, economic and industrial centers, among others that translates into economic viability, environmental sustainability, social equity and fairness, as well as politically democratic and participatory balance.

With respect to the above, Capello, Nijkamp and Pepping viewed sustainable city as a concept that refers to the potential of an urban agglomeration to ensure the development of a city through initiatives focused on the environment and the flow of energy that stimulates the Economic-social and environmental balance (Capello, Nijkamp, & Pepping, 1999).

However, this concept of sustainable cities is often presented as a long-term objective requiring a set of precisely social, political, economic and environmental policies integrating and moldable to each historical and social context of the city. Unfortunately, these policies are now threatened by population growth and the consumption of extra-metabolic energy which heralds the decline in natural resources.

Increase in population is one of the biggest concern of city managers, primarily due to the phenomenon of migration from rural areas to urban centres. According to a report by the United Nations *The World´s citizens in 2016,* it is estimated that 54.5% of the world's population lives in urban settlements and the 2030 estimate represents a significant increase in population in most

[1] Resilience is the capacity of a social–ecological system to maintain similar structure, functioning, and feedbacks despite shocks and perturbations (Stuart Chapin et al., 2012).

cities around the world, while the percentage of rural population will decrease by 5% (United Nations, 2016). The problem of increased population is perceived in 2 dimensions. First is concerned with space as city's boundaries must necessarily expand and not restricted to the surface alone but also the relationships and interconnections that the city has with its adjacent areas. Secondly is the supply, transformation and disposition of goods and services.

The extra-metabolic energy is the energy consumed beyond that which is necessary to supply the metabolic processes of survival, expressed as exosomatic energy or commercial energy (Costa, 2008; Ramos-Martin, 2006). This makes use of energy from external sources as natural resources to supply human-created needs such as oil extraction or electric power generation.

These two factors position cities as not only the largest consumers of resources and energy but also the major sources of pollution and environmental decay (Girardet, 1996). Constituting only less than 3% of the earth's surface (United Nations, 2016) cities remain the largest generators of greenhouse gases (GHG) with around 80%, are responsible for 75% of total energy consumption in the world, 50% of total waste generation and 75% global consumption of natural resources (World Bank, 2010).

This demonstrates that cities lead the processes of global environmental change in multiple scales significantly affecting the local and global biogeochemical cycles (Grimm et al., 2008). Not only for their contribution of GHG but mainly for the change in land use for urbanization and that needed to supply food, water, materials and energy to the city. The soil has played a fundamental role as a regulating agent within the carbon cycle through the capture of CO_2 in the form of organic matter. However, when organic matter is gradually diminished by agricultural and livestock overexploitation or practices of monocultures, use of chemical fertilizers, pesticides, burnings as well as deforestation, the balance in this cycle is decompensated bio-geochemically leading to global environmental change (Hernandez, 2017). *(Figure 1)*

This social, cultural, political and economic challenges facing global environmental change have directed the sustainability discourse in cities towards optimising the flow of food, water and energy.

This research is hence focused on food flows, seeing that in the face of population growth in cities, migration from rural areas to cities, soil degradation, pollution, inequality, waste and hunger, food flows in cities are becoming too significant to ignore on environmental agendas at local, regional and global levels (Maye, 2017). This attempts to answer the question of ***How it is possible to feed the cities in a sustainable, quality and efficient way?***

As inferred earlier, most of the resources entering cities are from their surrounding areas often regarded as *peri-urban* and food is not the exception. Eating food that is produced by ourselves, allows an equivalent exchange between the goods and services extracted from the ecosystems and the appropriation units (Toledo, 2008), which is considered an indispensable requirement for a sustainable food system. The Food and Agricultural Organisation of the United Nations (FAO) reported in 2013 that one-third of the world food production is lost or wasted every year during its flows of production, distribution, processing and consumption. **This is estimated at 1.3 billion tons**

per year (30% world food production), enough to feed 3 billion people, which in economic terms represents 750 billion USD (FAO, 2013).

Given this antecedent background, from conceptual bases of a system, ecosystem, and city in an attempt to present a clear relationship between the sustainability of the cities and the flows of food, it is easier to introduce the concept of Urban metabolism.

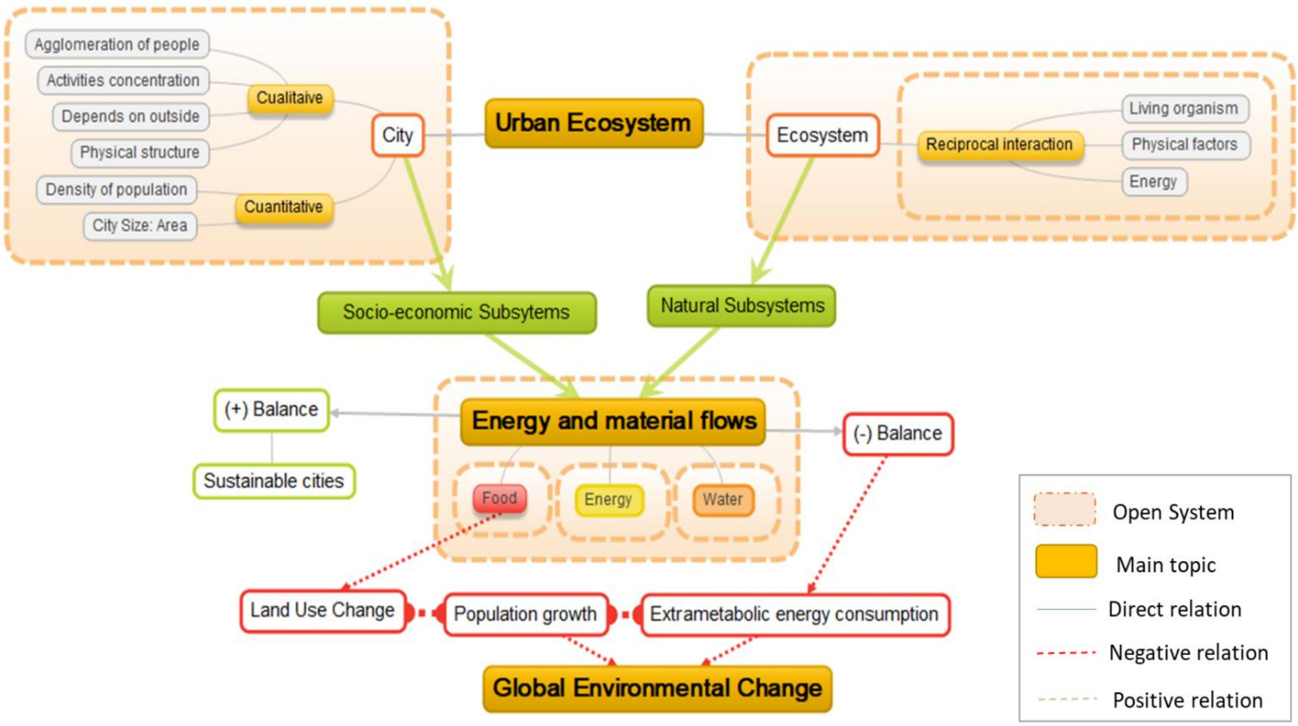


Figure 1: Introductory Mindmap
Source: Own elaboration

In the Urban Metabolism approach, cities as a living organism is an analogy that allows us to approach the environmental problem from a systemic focus, seeking to understand the dynamics of material and energy flows during the exchange between social groups and ecosystems. This exchange is given through processes of generation, appropriation, circulation, transformation, consumption and excretion (González de Molina & Toledo, 2014), This is also referred to as the social, technical and socioeconomic processes that take place in cities resulting from growth, energy production and waste disposal (Christopher Kennedy, Cuddihy, & Engel-yan, 2007). This is the rationale behind Urban Metabolism, a concept that will be further developed and explored.

1.1 Objective

The objective of this work is to evaluate the food flows in cities using the urban metabolism approach, a case study in the Northwestern Region of Rio de Janeiro state in Brazil. This study seeks to:

- Identify the food flows in the Northwestern region, its stakeholders, interrelations, process and sub-process with an urban metabolism approach;
- Define the system boundaries of specific food flows, based on a systemic analysis that allows visualizing the interconnections between the elements that set an urban ecosystem;
- Establish a food metabolic profile to enable the identification of critical points in the food flows;
- Identify the challenges for the food value chains in the Northwestern region.

These objectives are framed within the **Sustainable Development Goals** by the United Nations *No. 2 Zero Hunger* and *No.11 Sustainable cities and communities,* as a contribution to the current challenges of sustainability.

1.2 Thesis Limitations, Scope and Structure

As described earlier, the concept of a city is the place where people live and work. This also entails centers of government, commerce and transport that require inputs for their development, in addition to generating outputs. With respect to food flows, cities are considered as the largest food transformers. However, defining the borders or limits of a city presents the biggest problem in studies with such a focus. This work therefore is not an exemption and as such characterized by similar limitations.

Hence, this work utilizes conceptual tools and analysis as the Foodshed Assessment which is detailed in chapter II of this work. It seeks to determine the frontiers of food flows with an analysis of urban metabolism, first by an initial analysis conducted in the Northwestern region of the state of Rio de Janeiro and later narrowed down to the city of Itaocara.

Regarding resource flows, this work in its earlier chapter outlined the general description of the flows in the Northwestern region of the state Rio de Janeiro. However, due to economic, environmental and social importance of these flows, it is later scaled down to dairy and horticulture flows. It is important to note that dairy flows here refer particularly to raw milk flow and its main derivatives such as cheese and butter, while horticulture flows refer only to the flow of vegetables and fruits.

Data used for this study is subject to information provided by government entities in the state of Rio de Janeiro. However, it is insufficient for analyzing the flows of matter and energy. On account of this, the analysis is addressed in a more descriptive form, supported by quantitative data obtained from the field but do not represent quantities that allow for generalizing the results as reflective of the whole region.

During the quantification of food flows, the measurement of food wastage is made taking into account the percentages of waste for dairy and horticultural flows in Latin America established by FAO in 2011. This means that the efficiency of food flows refers to a theoretical efficiency, given that calculation of a real efficiency would demand other time, economic, logistical and human resources that extend the scope of this thesis work.

On the other hand, the study of the urban metabolism has developed different methodologies with different approximations and systems of indicators (Benavides, 2017). However, for analysis conducted in this work, the Material Flow Analysis (MFA) intensely investigated by Brunner, Baccini and Rechberger (P. Brunner & Rechberger, 2005) is considered as the tool of analysis.

The preceding reasons present the basis to outline the structure of this research work: Chapter I is an introductory chapter which show the relationship between Urban Metabolism, Food Security, Sustainable cities and Global Environmental Change. Chapter II focuses on developing the conceptual framework based on concepts of urban metabolism and Foodshed assessment. Chapter

III introduces the Northwestern region of the state of Rio de Janeiro in Brazil and validates the selection of Itaocara city as the study area carrying out an analysis of the social, economic and environmental dimensions, as well as presenting a legal framework regarding food security in Brazil and governance in cities. Chapter IV presents the results, delving into the development of production, transport, marketing, distribution, consumption and waste processes within dairy and horticultural flows. Chapter V shows the data and information analysis, using the MFA methodology, Sankey diagrams and the identification of Foodshed. In this chapter also are presented the challenges for regional food value chains. Finally, in Chapter VI are presented the conclusions.

1.3 Methodology

This work sets up a methodology that includes the use of different methods and tools that allow the fulfillment of the proposed objectives. According to the development of the research process, the methodology is divided into three parts. *Table 1* below presents each part connected with a method and each method linked with tools used:

Table 1: Working Methodology

Research process	Method	Tools
Part 1: Identification and description of food flows	Data collection	Sources of Information
		Interviews to stakeholders
		Direct observation
		Bibliography review
		Public and private institutions Reports and Informs
Part 2: Definition and identification of system boundaries	Foodshed assessment	GIS: Geographical Information Systems
Part 3: Analysis of data under urban metabolism approach	MFA (Material Flow Analysis)	Selection of meta-indicators for inflows and outflows
		Graphic representations in Sankey Diagrams

Source: Own Elaboration

The following paragraphs present the criteria taken into account for selecting methods and tools that configure the working methodology.

1.3.1 Data Collection

The first step in the research process is the identification and description of the food flows during production, transportation, distribution, marketing, consumption and waste. These processes set food flow as a base information for whole research work.

The identification was made through field visit to the study area. An investigation was carried for 60 days in the northwestern region of Rio de Janeiro state. During this period was contact established with the offices of EMATER - Empresa é responsável pela assistência técnica e extensão rural no Estado do Rio de Janeiro (Company responsible for technical assistance and rural extension of Rio de Janeiro State) and the International cooperation project RIORURAL.

Sources of information

A list of stakeholders and information sources is showing in *Table 2* for the identification of the general food flow within the state was outlined with support from EMATER and RIORURAL.

Table 2: Main Information sources

Information Sources
• **IBGE - Instituto Brasilero de geografía e estadística (Brazilian Institute of Geography and Statistics)**
• **SEAPEC -Secretaria de estado de agricultura, pecuaria, pesca y abastacimiento (Secretary of State for Agriculture, Livestock, Fisheries and Supply)**
• **EMATER - Empresa é responsável pela assistência técnica e extensão rural no Estado do Rio de Janeiro (Office responsible for technical assistance and rural extension not State of Rio de Janeiro)**
• **PESAGRO - Pesquisa e desenvolvimento tecnológico no segmento agropecuario no estado de Rio de Janeiro (Research and technological development on agricultural segment on Rio de Janeiro state)**
• **EMBRAPA -Empresa Brasilera de pesquisa agropecuaria (Brazilian agricultural research office)**
• **CAR - Cadastro ambiental rural (Rural environmental register)**
• **CEASA - Centrais de abastecimento do Rio de Janeiro (Central supply offices of Rio de Janeiro state)**
• **Secreatria de saúde de Rio de Janeiro (Health secretary of Rio de Janeiro state)**
• **INEA - Instituto estadual de Ambiente (State Environmental Institute)**
• **CEDAE - Companhia Estadual de Águas e Esgotos (State Water and Sewage Company)**
• **RIORURAL Project - Word Bank**

Source: Own Elaboration

Other information sources such as Cadastro Nacional de Produção organica (National Register of Organic production), Associação de agricultores biologicos (Biological farmer's association), Conselho Regional de Engenharia e agronomia (Regional engineering and agronomy council), Articulação agroecologia de Rio de Janeiro (Agroecological articulation of Rio de Janeiro), among others, could not be incorporated due to their location and difficulty in accessing information.

From the list of available information sources, a matrix that links the basic information necessary for this research work with the stakeholders or entities that could provide needed information was made, taking into account three criteria:

Accessibility: When the entity has the information and could be accessed through online, reports, visits or interviews. This also refers to the capacity to access information taking into consideration the availability of resources such as human, economic and logistical support.

Availability**:** When the entity had the will and permission of provide or give out their information in the shortest possible time within a 30-day maximum response time.

Reliability: When this information belonged to government entities, available for public knowledge and used as a basis for regulation and control processes in Rio de Janeiro State, for example, as a basis for tax calculations or reports officers.

The matrix highlights the information provided by the list of entities that meet the above three criteria. This matrix is presented in Annex 1: Data accuracy. In evaluating the matrix, the "traffic-light" methodology was used, where the colour green indicates that it complies fully with the criteria, yellow indicates that there is no certainty, and red indicates that it does not meet the criteria.

Interviews

Taking into account the available time for the field work and information needed, 25 interviews were conducted to identify the process in the food flow from the information sources and later also to the main actors and stakeholders within the flow. This includes producers, farmers, associations, retailers, consumers, public and private institutions such as central bank and dairy cooperative in the municipalities. The interview sought to obtain information in an open manner. Hence, it was not subject to a list of questions that restricts the possibility of expression beyond the information provided in a specific questionnaire. However, an interview format, presented in Annex 2 was used to propel the flow of information.

The implementation of surveys was however not taken into consideration due to the economic and logistical resources for the application of a specific questionnaire to a representative sample of the population. In the case of food flows, the actors within were not available, and in the case of information sources, the survey was not considered an appropriate instrument.

Direct Observation:

To validate the information provided by different entities, field visits were carried out through associations of producers, and were was possible, accompanying transportation, collection and distribution routes of food. Also, three trips were made to the marketing centers and sale of food. During these visits, photographic records were made and presented in Annex 3, alongside the collection of information through interviews.

Literature Review:

During the development of the research process, there was access to different sources of primary and secondary information such as databases and reports issued by the entities at the local, regional and national level. This includes the Development Plan of the State of Rio de Janeiro and reports of the World Bank, FAO, United Nations among many others at the international level and in addition to the consultation on web pages. A review of relevant literature was also conducted using scientific and academics journals from different entities such as EMATER research tools provided by UASLP and ITT. Selected keywords were used as a search criterion for determining the most appropriate bibliography from which a database comprising of texts, case studies, research journals, reports and web pages most relevant for this investigation was established. For managing bibliographic references *Mendeley* referencing tool was used due to its ease of handling and prior knowledge of its use.

1.3.2 Method for System Boundaries Identification

The Foodshed assessment is considered as a methodology used in urban planning to further understand the food needs and the ability for self-reliance. This methodology allows planners and decision-maker visualize the food flows geographically and provides access to more data to manage the current and future land uses.

During this study, it was determined that the methodology of Foodshed assessment provides a very viable solution to one of the main limitations in Urban Metabolism studies, which is precisely the determination of the boundaries of the system under study.

The Foodshed is a geographic area within which food for a population originates (Blum-Evitts, 2009). Foodshed assessment aims to determine a geographic area that represents the flow of foodstuffs from its origin to consumer markets (Brinkley, 2013). A foodshed is presented as an analogy of the watershed: where the "headwaters" of the foodshed are the food producers: farmers, ranchers and fishermen, the "tributaries" of the foodshed are represented by the food distribution mechanisms, grocery stores and shipping lines and the "discharge area" of foodshed is the consumer. This image of tributaries that flow into the rivers helps to connect the often disparate parts of a food supply for local and regional planning (Fradkin, 2015).

This methodology uses as an input of information the local mapping and statistics. However, defining the scope of a local foodshed is not yet an established process (Blum-Evitts, 2009). In practice, the foodshed assessment is formed by production points, farmlands location, transportation routes, regional geography and markets, rather than political boundaries. Usually, this methodology consists of three phases: a) determining current local food production b) determining the consumer food demand and c) determining the potential local food production. However, for the present work, the first two phases are used, in addition to available information on land use, land appropriation and also using Geographic Information Systems tool (GIS), the determination of routes of transportation, marketing and distribution of food are taking into account to determine the foodsheds.

GIS is an important tool that has been used in studies of urban metabolism, most importantly the material stocks analysis and studies related to the flows of carbon emissions (Benavides, 2017; Christen, Coops, & Van Der Laan, 2010; Minx et al., 2011). In this research work is considered that software such as ArcGIS allows for the spatial definition of the food flows as well as the visualisation of information that determines the foodshed. As stated by Benavides 2017, research provided by the GIS tools have not been deeply implemented to studies of urban metabolism, except in some cases. However, the study highlighted the opportunity to use these tools given its wide range of utility.

1.3.3 Method for Urban Metabolism Analysis

The analysis of flows of matter and energy is constituted as a base tool and starting point for the analyses of urban metabolism (Zhang, 2013). However, research, adaptations and a great number of models and tools have been developed all over the world. In this work, different analysis methodologies are evaluated with reference to Benavides 2017.

One of such tools is the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) which is a metabolism analysis tool that considers mathematical calculations and equations, multiscale, multidisciplinary and complex analyses. It is considered as whose theoretical development relies heavily on complex adaptive systems theory. Its objective is to integrate criteria as nested hierarchies, unpredictable loops and a multiple operation scales for analysis (Giampietro, Mayumi, & Ramos-Martin, 2008).

Other tools are input and output calculations based on black box analysis; emergy analysis and material flow analysis (MFA). The former is calculated as the energy contained in the flows of materials, energy and information or the mass of a material flow multiplied by the value of solar transformation (Zhang et al., 2008). Emergy analysis takes into account different forms of energy and resources, where each of the forms of energy is produced through processes of transformation in nature with certain capacity to perform work, both in ecological and human systems (H. T. Odum, 1996).

The MFA, on the other hand, is a systemic methodology developed to account for different flows and stocks of materials within a system defined in space and time (P. Brunner & Rechberger, 2005). It is defined as a method to quantify the flows and stocks of materials in arbitrarily complex systems (P. H. Brunner, 2002). MFA has been widely applied to material systems in providing important and useful information regarding the patterns of resource use, and the losses of materials entering the environment. With respect to this study, it is used as food flow analysis.

Other monitoring and assessment methodologies for calculation of ecological footprint were evaluated. The ecological footprint is defined as: Unique (integrated) and descriptive index indicator that shows how many hectares of nature are needed to supply the productive processes and to absorb the waste generated by an economy (Guerrero & Guiñirgo, 2008).

On the other hand, the Life Cycle Analysis (LCA), is a method standardised by the International Standards Organizations through the ISO 14040/14044 norms. It assesses the environmental aspects and impacts of a product or service throughout its lifecycle, including the acquisition of raw materials, production, transportation, distribution, marketing and final disposal. LCA is defined as the phase of cycle life assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle (The International Standards Organisation, 2006).

Model accuracy selection:

For the development of the third part of this work, a prioritisation of the different models was carried out in order to choose the most accurate methodology and apply it through a case study.

Eight Meta-criteria, considered as fundamental for selection of the most accurate method of food flow analysis, were taken into account for the prioritisation. For each of the meta-criteria, a relationship coefficient was assigned, according to each of the objectives of this research work. These are shown in *Table 3:*

Table 3: Meta-criteria selection and relationship coefficient

Meta-Criteria	Relationship with Objective 1: To identify the system boundaries under a systemic analysis	Relationship with Objective 2: To establish a metabolic city profile	Relationship with Objective 3: To identify the challenges for developing the food value chains	Coefficient
Approach systemic				1
Comprehensible methodology				0,8
Results easily communicated				0,3
Use of the scientific method				0,8
Popularity and acceptance				0,3
Application in Environmental Sciences				0,3
Application in cities				1
Transferable information capacity				0,8

Complete relationship between the Meta-criteria and the Research Objectives

Source: Own elaboration

Then, a matrix was made to evaluate the Meta-criteria with respect to the models obtained from review of related literature for the analysis of urban metabolism. This matrix performs an evaluation according to the literature review where the following scale was used:

0 = Does not meet the criteria

1 = It is necessary to review more in-depth and study other case studies

2 = Meets the criteria

Table 4: Evaluation of Urban Metabolism analysis models

Meta-Criteria \ Analysis Methods	Multiscale, multidisciplinary and complex analyses MuSIASEM	Input and output (black box) analysis	Emergy analysis	Material flow analysis (MFA)	Ecological footprint	Life cycle analysis
Approach systemic	2	0	2	2	0	0
Comprehensible methodology	0	2	1	2	2	2
Results easily communicated	0	2	1	2	2	2
Use of the scientific method	2	2	2	2	2	2
Popularity and acceptance	0	2	1	2	2	2
Application in Environmental Sciences	1	1	2	2	2	1
Application in cities	1	1	2	2	1	1
Transferable information capacity	1	2	1	2	2	2

Source: Own elaboration

Taking into account that each meta-criteria has different proportions of representation according to their importance for the fulfilment of the research objectives of this study, a matrix is finally developed for the selection of the most accurate method of analysis. Here, the coefficients are multiplied by results in the matrix evaluation of analysis models. It is shown in the *Table 5:*

Table 5: Analysis model accuracy selection

Meta-Criteria \ Analysis Methods	Coefficient	Multiscale, multidisciplinary and complex analyses	Input and output (black box) analysis	Emergy analysis	Material flow analysis (MFA)	Ecological footprint	Life cycle analysis
Approach systemic	**1**	2	0	2	2	0	0
Comprehensible methodology	**0,8**	0	1,6	0,8	1,6	1,6	1,6
Results easily communicated	**0,3**	0	0,6	0,3	0,6	0,6	0,6
Use of the scientific method	**0,8**	1,6	1,6	1,6	1,6	1,6	1,6
Popularity and acceptance	**0,3**	0	0,6	0,3	0,6	0,6	0,6

Application in Environmental Sciences	**0,3**	0,3	0,3	0,6	0,6	0,6	0,3
Application in cities	**1**	1	1	2	2	1	1
Transferable information capacity	**0,8**	0,8	1,6	0,8	1,6	1,6	1,6
Total		5,7	7,3	8,4	10,6	7,6	7,3

Source: Own elaboration

However, it must be noted that the prioritization table is presented here in a simplified way Where from a general analysis of the different approaches, it establishes general criteria, it is referred here to as meta-criteria.

As can be observed, the MFA method ranked top with the highest score with 10.6. This is because meta-criteria related with practicality, information management, easily communicated results and usefulness. Using the last prioritisation matrix, it is possible to identify that in accordance with the purposes of this work, the methods of LCM, Footprint and Black Box present very similar conditions. However, the systemic approach required in the methodology of this research is beyond of the scope of the latter methodologies. On the other hand, the Emergy analysis shows the second score in the prioritisation. Nevertheless, the ability to handle the information is a disadvantage that does not allow its implementation.

This result obtained can be inferred from previous studies by Benavides in 2017 where a detailed bibliographical review of different methodologies used for the analysis of the urban metabolism was carried out, and the conditions, advantages and disadvantages for each method presented. (Benavides, 2017).

According to these two aspects; the matrix of meta-criteria and the bibliographical review by Benavides 2017, it was determined that for development of the present study, the methodology that can be used to achieve the objectives of this study is offered by the Material Flow Analysis.

Material flow analysis (MFA):

The MFA seeks mainly to define and evaluate in quantitative terms a system of flow and stock of materials, reducing to the maximum the complexity of the system to allow decision making in the administration of resources, environment, and waste, based on understandable, reproducible and transparent information (P. Brunner & Rechberger, 2005).

This methodology has been broadened by researchers such as Brunner, Rechberger and Baccini who found their main application in the industrial, economic and urban planning fields. The MFA is an appropriate tool to investigate the flows and stocks of any system based on materials. It gives an idea of the behaviour of the system, and when combined with other disciplines such as the analysis of the energy flow or the economic analysis, it facilitates the control of an anthropogenic system, which Brunner and Baccini refer to in a book *Metabolism of the Anthroposphere* (1991). Here the concept of anthroposphere defined as the global network of urban systems that involve aquatic and terrestrial ecosystems and the concept of metabolism as flows and stocks of materials and energy within this network.

Recently, MFA has been strengthened in the study of urban metabolism through the combination of indicators already defined. For example, EUROSTAT indicators to establish procedures that allow the identification of the borders of a system and the subsystems analysis. The MFA methodology has also evolved into concepts such as Analysis of Substance Flows (SFA) and also when combined with analysis of energy flows (MEFA), it is considered as one of the main tools for the analysis, not only for urban metabolism but also at regional and national level. The MFA is also considered a very useful tool in the analysis of industrial metabolism within the framework of industrial ecology.

For the development of this methodology based on Christopher Kennedy researches (Christopher Kennedy, Baker, & Brattebø, 2014), the need for selecting meta-indicators that allow for quantitative visualization of food flows like inputs and outputs is hereby realized. This is presented in a detailed form in Chapter IV.

In multiple studies, the MFA method uses Sankey diagrams as visualization tool, which are widely used to visualize energy, materials, resources and substances flows(Lupton & Allwood, 2017). Sankey diagrams allow the understanding of losses and inefficiencies within a system, as well as the understanding of the processes that set the system. The Sankey diagrams is also used within the scope of this work as a tool for visualization of the MFA.

2 Two Fundamental Concepts: Urban Metabolism and Foodshed Assessment

Favela in Rio de Janeiro. Photo taken by Moon, 2018

"The more we study the major problems of our time, the more we come to realise that they cannot be understood in isolation. They are systemic problems, which means that they are interconnected and interdependent"

Fritjof Capra

This chapter introduces two key concepts for the development of this research: Urban metabolism and the Foodshed assessment, both probably not very popular but have been arduously researched, developed, and implemented for several years around the world.

Increasingly, the growing communities concern for the future and the environment becomes more common due to the threat of economic systems over their traditions, customs, territories and even over their survival. The economic system as development based on money and power accumulation is putting at risk the availability of natural resources that allow the human survival on the planet. Water, food, land are resources without a substitute, meaning, if we put at risk their availability, we put at risk our life. In the case of food, this is leading to the emergence of "fake" foods that are produced through technologies, do not guarantee the health of consumers and in addition carry on serious social and cultural problems (Bucher, Müller, & Siegrist, 2015). These "fake" food are sold at prices that appear to be very cheap and readily available but ideally they have an incalculable cost to the for society and the planet.

This situation adds to extractive systems driving to communities for development and finding ways that allow them to improve the coexistence between humans and nature. Where possible, it seeks to develop mechanisms that ensure the health of the people, their food security and overhead all their survival on the planet (Food and Agriculture Organization of the United Nations & Platform for Agrobiodiversity Research, 2011; United Nations Global Compact Office, 2008).

Therefore, is necessary to understand these two concepts; on the basis of the objectives that drive this study, for the description and identification of food flows, and to visualise the critical points within these flows. In the first part of this chapter, these two concepts are addressed separately, and the chapter concludes by presenting the relationship that exists between both concepts and their applicability in this study.

2.1 Urban Metabolism

Understanding cities as living organisms is an analogy that allows us to address the environmental problems from a systemic approach where we seek to understand the dynamics of the flows of matter and energy during the different processes that develop in the city (González de Molina & Toledo, 2014). From this approximation, different conceptual frameworks emerge, which are traduced in tools that allow to understand, monitor the cities dynamics and also to visualise in a holistic way the environmental, social, economic and political problems faced by citizens. These tools also allow model strategies with a focus on sustainable solutions. In this context, urban metabolism is considered as one of the concepts that have evolved to become one of those tools not only for city managers but to solve the current environmental problems.

Urban Metabolism is a model[2] which illustrates the transformation of resources into useful elements for a city, as similar to human metabolic processes or ecosystem processes (Zhang, Yang, & Li, 2006). From a human perspective, that includes the social, political, economic and natural aspects of sustainability.

2.1.1 **Conceptualization and Historical Evolution**

The concept of urban metabolism would be thought to be relatively new. However, before the 19th Century, Karl Marx and Friedrich Engels already recognised the alterations caused by human beings on the natural environment through the analysis of energy transfer between this Man-Nature relationship (Schmidt, 1976). In fact, they present the first approach to the concept of metabolism or "*Stoffwechsel*", as the set of exchange relationships that is present between nature and society (J. Martínez-Alier, 2003).

Later, towards the end of the 20th Century, the field of the economy once again used this concept to carry out the analysis of material flow, until it managed to tackle fields such as human health, social development and economic growth (Toledo, 2013).

Currently, urban metabolism is interpreted as an instrument that allows the approach of contemporary environmental problems from an integrative and systemic perspective that has methodologies and sources of statistical information that make it easier to carry out particular metabolic profiles at local, regional and global level.

The study of urban metabolism is based on the analysis of flows of matter and energy. These flows are reflected in the exchange of water, work, information, energy, food, services, people, money,

[2] A model is a representation of the reality that serves to determine the sensitivity of an ecosystem to the change of a variable. A model does not predict the future.

chemical and organic compounds, fauna, flora. In general, it consists of goods and services in the form of matter and energy that flow and are processed and transformed into ecosystems. Under this approach, cities are intimately connected to natural systems through roads that are most often invisible or barely identified by the city's inhabitants themselves (Day, John W; Hall, 2016).

Studies on the urban metabolism in cities can contribute to solving ecological and environmental problems, given that an analysis of the demand of the urban ecosystem (Bodini, Bondavalli, & Allesina, 2012) is carried out on the various natural resources and the pressure of the waste that are discharged from the same urban ecosystem back into the environment (Zhang, Yang, & Yu, 2008).

This approach visualises the city as a highly dependent system of material and energetic inputs from external ecosystems, which are most often geographically distant and with different limitations of availability. (Guerrero & Guiñirgo, 2008), For this reason, the understanding of the dynamics of urban metabolism and the pressure exerted on its local, regional, global supply and discharge networks is decisive for the determining critical points that endanger natural ecosystems and the social and economic development of the city. *(Figure 2)*

The notion of identifying cities as living organisms or ecosystems under the model of urban metabolism has also been strongly discussed and criticised. However, cities and natural ecosystems are both types of complex systems that depend on their external environments to obtain resource as inputs and for the assimilation of wastes as outputs, and this a characteristic of living organisms metabolism.

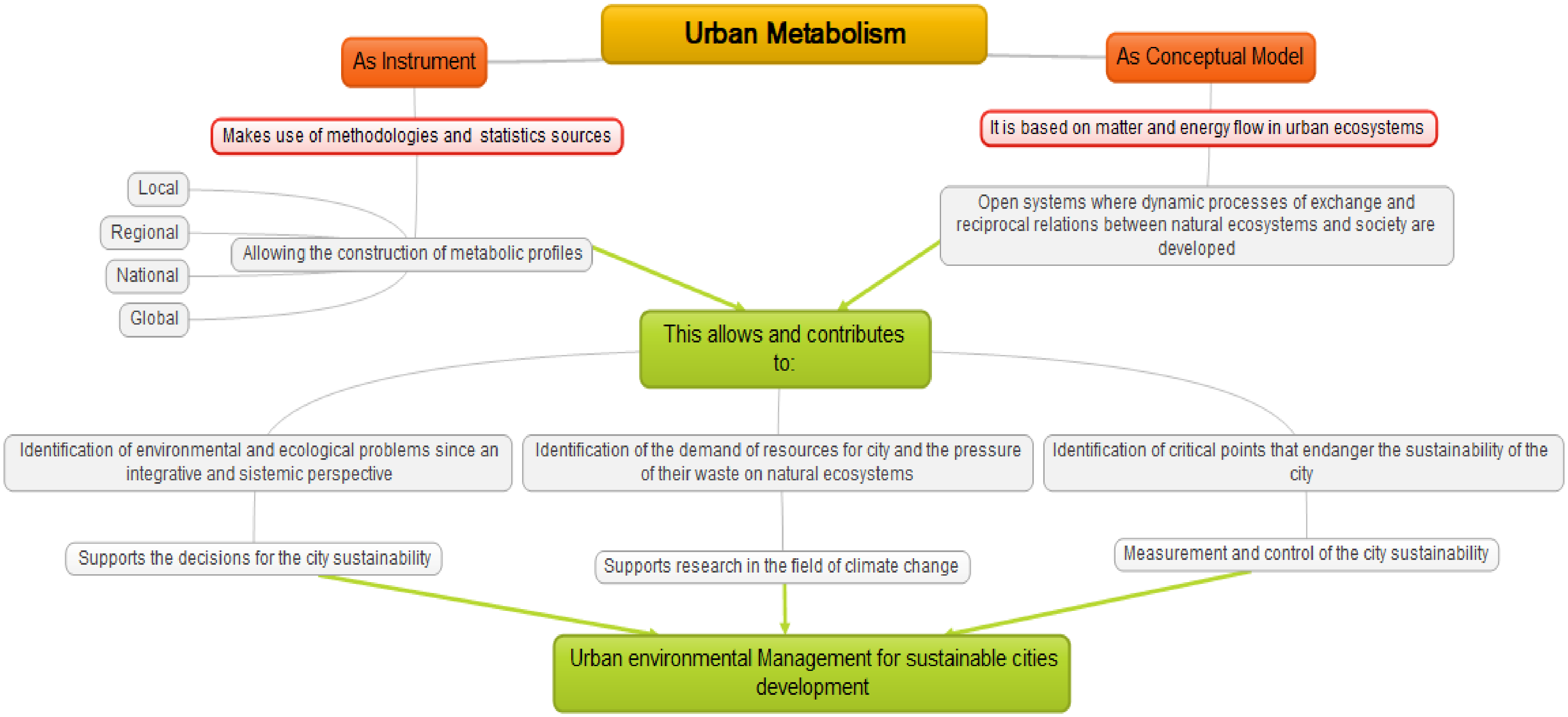


Figure 2: Urban Metabolism Conceptualization
Source: Own Elaboration

In 2007, Christopher Kennedy in the company of a team of engineers of the University of Toronto established that the urban metabolism referred to ***the total sum of the social, technical and economic processes that take place in the cities as results of growth, energy production, and waste disposal*** (Christopher Kennedy, Cuddihy, & Engel-yan, 2007).

Subsequently, a study of urban metabolism by Christopher Kennedy and researchers as Larry Baker and Helge Brattebo (Christopher Kennedy, Baker, & Brattebø, 2014), developed a practical guide to identify the elements that should be considered in an Urban metabolism analysis, wrapping the quantification of inputs, outputs, storage and production of energy and materials within an urban frontier. However, reaching this point of analysis has been the result of several years of research.

In 1965, Abel Wolfman made the first approximation to the concept of Urban Metabolism in his book *The Metabolism of the city*, confirming the flows of materials, information, energy and resources through the cities. In 1976 Alfred Schmidt, Julia M. T. Ferrari de Prieto and Eduardo Prieto re-evaluated the relationship man-nature, established from Marxism to contribute also to these first approximations to the concept. (Schmidt, 1976).

However, these first definitions were preceded by the evolution of ecological and physical concepts. For example, the concept of energetic ecology established by Sergei Podolinsky in 1880, which also refers to the energy efficiency equation where five inverted calories should produce one calorie in human work form. It is known as the principle of Podolinsky (J. Martínez-Alier, 2003). Geddes in 1885 also developed a unified concept, in which he provides a framework to link the economic and social activity integrating the process of extraction, manufacture and transport of energy and materials, taking into account the losses, contributing to the bases to establish the processes of the urban metabolism. Likewise, concepts such as endosomatic and exosmotic energy developed in 1921 by Alfred Lotka, made their contributions to what is also known today as bio-metabolism and techno-metabolism (González de Molina & Toledo, 2014).

In 1969, sciences such as geography began to identify the metabolism of cities as a central problem in their area of study. In 1970 the scientist Howard T. Odum developed the concept of emergy, which would become one of the models for quantification of energy flows. Odum identified the emergy as the energy contained in the flows of materials, energy and information or the mass of a material flow multiplied by the solar transformation value (Odum, 1996).

Girardet in 1990 realised that a linear sequence in the supply of the environmental resources to city and the generation of products and wastes was not similar to the way real organisms influence the ecosystems that support the life on the earth. Consequently, he proposed a cyclical urban metabolic model (Girardet, 1996). Researchers Baccinni and Brunner in 1990 established as a tool for urban metabolism the Material Flow Analysis (MFA), which allows for monitoring flow of materials through its entire life cycle within an urban system and this emerged as one of the main tools for urban metabolism model (Pincetl, Bunje, & Holmes, 2012).

About three decades after the Wolman approach, this concept was again reawakened in 1999 by Peter W.G. Newman *(Figure 3)*, which identified the importance of sustainability in cities and established the first model of urban metabolism. Newman proposed a model that expands the concept of urban metabolism. With consideration of social factors (health, education), it focused on considering the inputs and outputs of materials, the dynamics of settlements and the habitability in the city. For the purposes of this study, an adaptation to this model is made highlighting the processes that involve the food flows.

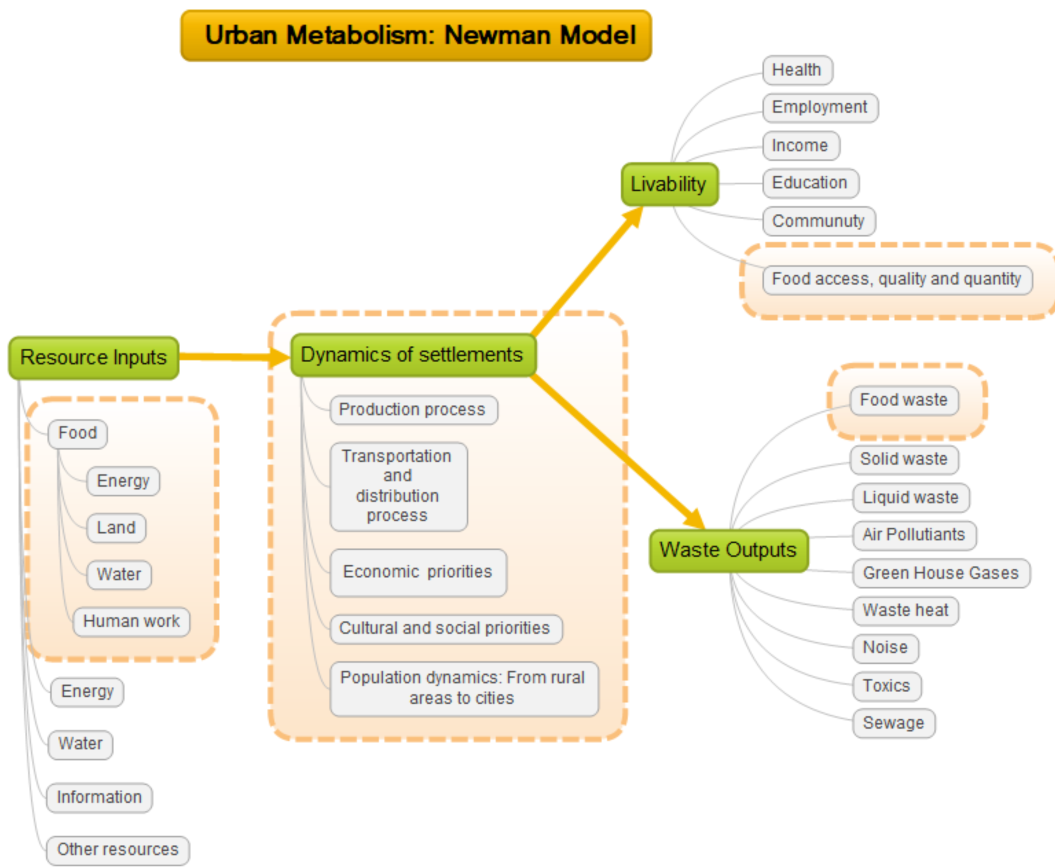


Figure 3: Newman´s Urban Metabolism model
Source: Newman, 1999. Adapted

However, it was until the beginning of the 21^{st} century that the applied studies of urban metabolism in the cities began. This first step was mainly in Asia where scientists such as Shu-Li Huang, Chia-Wen Chen, Yan Zhang, Zhifeng Yang, Wei Li and Xiangyi Yu started with the analysis of urban ecosystems, introducing, in turn, this concept. In his studies, the identification and measurement of the variables that interact in an urban ecosystem are highlighted. (Zhang et al., 2008)

After the signing of the Kyoto Protocol in 2007; where the participating countries committed themselves to reduce greenhouse gases to mitigate climate change, an important amount of research was carried out focusing on the sustainable cities, and the concept of urban metabolism was consolidated. It presented the model of urban metabolism as a viable and useful tool to support the decisions of urban environmental management directed towards sustainability, in addition to its monitoring and measurement.

In the following years, important studies were conducted where the concept of urban metabolism was put into practice in fields such as urban planning, citizen participation, environmental justice, economic ecology, surface occupation through SIG tools and the planning of sustainable cities (C Kennedy, Pincetl, & Bunje, 2010).

In several Latin American countries, there has also been an important approximation to the study of metabolism in the cities. However, it is more specifically oriented to the term of Social Metabolism, developed by Víctor Toledo who expresses the view that the Social Metabolism allows us to address the environmental problems from a systemic approach that seeks to understand the dynamics of the flow of matter and energy during the processes of generation, appropriation, circulation, transformation, consumption and excretion in the exchange between social groups and agroecosystems (Barrera-Bassols & Toledo, 2008; González de Molina & Toledo, 2014; Toledo, 2008, 2013). This approach is deeply investigated in section 2.1.4.

The concept is currently being decisive in research on climate change, since it allows the inventory of Green House Gas emissions and land use change becasue urban metabolism is considered as a model that presents key elements for the development of plans that influences decrease consumption and the conservation of natural resources.

In *(Figure 4)* the most significant milestones can be visualised in the chronological evolution of the urban metabolism concept.

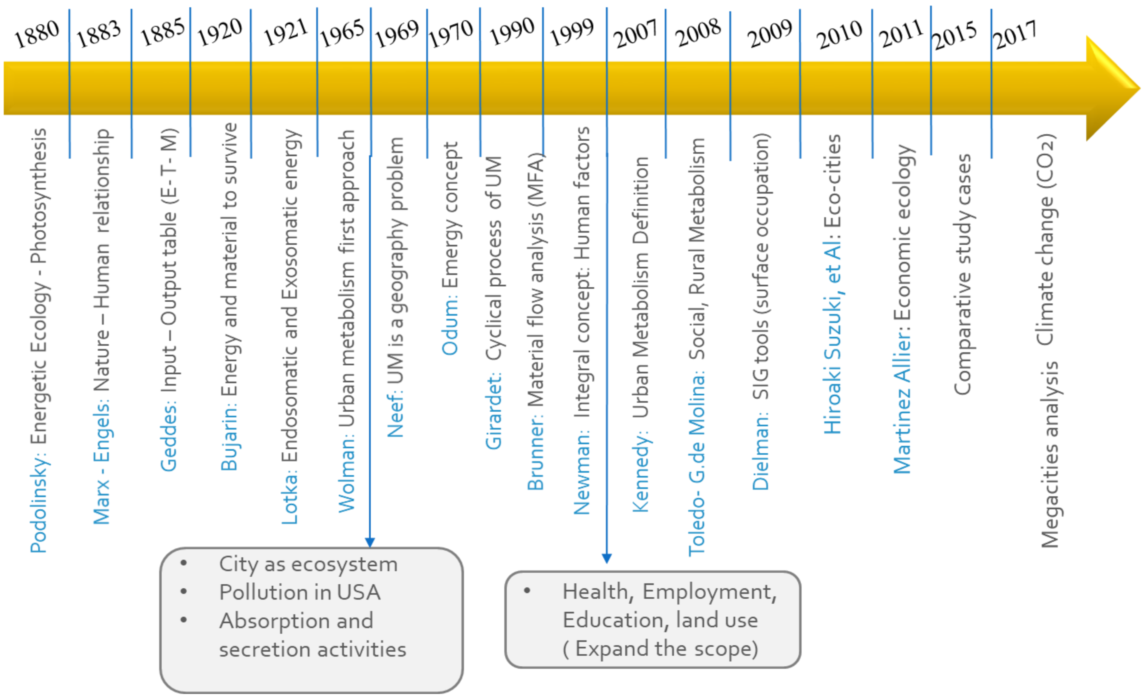


Figure 4:Milestones in the chronological evolution of the urban metabolism concept
Source: Own elaboration

2.1.2 **Systems Theory and Hard Systems Thinking**

Urban Metabolism holds its conceptual bases to system thinking (Randle & Stroink, 2018) and systems theory (Meadows, 2009). Here the city is presented as an open system that interacts with other systems and is composed by subsystems where processes dynamic, complex and open are carried out to determine their intrinsic and emergent properties and their characteristics past, present and future, defining the city as a living system.

According to Randle and Stroink, System Thinking is a cognitive paradigm with which people perceive themselves and the world as dynamic entities that display emerging patterns continually, those arising from the interactions among many interdependent, connected components. In easier terms, Michael C. Jackson in his book *System Thinking: Creative holism for managers* explained this concept by associating the System thinking with the capacity of obtaining solutions which work in the face of significant complexity, change and diversity. He affirms that ***" Simple solutions fail because they are not holistic or creative enough".*** (Jackson, 2003)

Making a general analysis in the Systems Theory and Systems Thinking for the development of the concept of Urban Metabolism, the following can be assumed based on Michael C. Jackson research:

There are four types of System approaches *(Figure 5)* in which the Systems Thinking is based viz;

Type A (based on mutual agreement): These are approaches based on the search and viability through increasing the efficiency and effectiveness of the processes and structures of the systems. Within this type are found: Hard Systems Thinking-(HST), System Dynamics, Organizational Cybernetics, and Complexity theory. The HST is a linear method that emerges as an adaptation of the scientific method to make this applicable to real-world problems. On the other hand, the Cybernetic models try to manage issues of complexity and turbulence that are beyond the handling capacity of the HST approaches. These model remain viable in rapidly changing contexts.

Within Type B are approaches that seek to improve the system performance by exploring purposes and ensure one sufficient agreement. These are based on a discussion about the purposes including Strategic Assumption, Interactive Planning and Soft Systems Thinking. The latter, assumes that problem context are pluralist and provide recommendations for analysis and intervention on that basis. The Soft Systems Thinking represent an approach agreed on goals that could be used to provide an objective account according with the system purposes.

In Type C approaches, the main concern shifts to ensure fairness in systems. These are critical systems heuristics[3] (Neth & Gigerenzer, 2015) and Team Syntegrity[4] (Malik, 2010) and finally, the Type D where the approach of Postmodern System Thinking faces the challenges of standardisation, routine and further the difference, fun, creativity and human emotions.

Into these categories, different paradigms of thinking about systems emerge which could be a combination of one or more of the different categories according to the goal or purpose research approaches. Those are deeply detailed in Jackson book, mentioned above. For the purposes of this research, only the Hard Systems Thinking approach is expanded, given that the same objectives are identified under this approach.

[3] Heuristic is the art and science of discovery and invention or solving problems through creativity and lateral thinking or divergent thinking (Neth & Gigerenzer, 2015).
[4] Syntegrity is a formal model presented by Anthony Stafford Beer, a British theorist, in his work on management cybernetics, the science of large, complex, probabilistic systems (Malik, 2010).

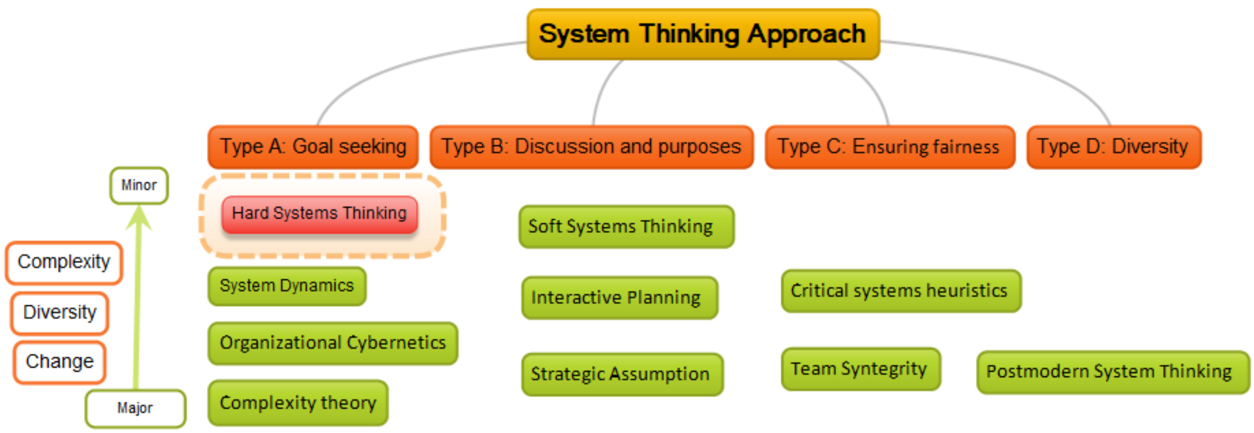


Figure 5: Systems Thinking Approach
Source: Own Elaboration based in Jackson 2003

The Systems approaches described in type A aims to assist decision making organisations and entities to improve goal seeking and viability. These models are focused on: efficient use of resources, achievement of goals, effective design or organisations, achieve prediction and control for better regulation. Conversely, the HST models help managers (public and private decision and policy-makers) to scientifically solve problems and resolve the policy issues that they face and not just for knowledge advancement. This correlates with the last objective of this research work.

However, the HST models also have some limitations. One of this is its attribution to "Reductionism", as it attempts to mathematically model the elements and variables on the problem, in addition to identifying the multiple interactions and the quantification of their influence on the problem. Critics argue that the model is unable to satisfactorily deal with multiple perceptions of reality. Other limitations are related to the strategies in the HST, which build from a clearly defined target, without allowing adaptations of it. This situation is reflected in results used as recommendations that should generally be developed by political leaders or governmental institutions with ties to power. However, the HST are models linked to a systematic methodology to deal with the problems and is usually preferable as a methodology approaches as compared to other *Ad hoc* methods based on the common sense of the decision makers.

According to M.C Jackson (2003), the HST finds the best means of getting from the present system state to some optimum state and the use of mathematical models are crucial to its success. These models capture the essential features of the real world depending on available information in order to determine the system behaviour. Currently, the HST are seen as models that offer a broad approach to the solution of problems in transport, housing, infrastructure and environmental systems.

Under this approach, "*Urban Metabolism constitutes a useful, flexible concept, certified and recognized by academia, industry, society and government, which helps in the understanding of cities and their dynamics, and in the search for their permanence in the Space and time, this due to the versatility of his notion from the technical, multidisciplinary, ecological and economic perspectives* " (Díaz Álvarez, 2014).

2.1.3 Matter and Energy Flows

As established in the previous chapter, the flows of matter and energy constitute the conceptual basis of the study of urban metabolism. Through these it is easier to trace the transformations of elements and substances in a city (P. Brunner & Rechberger, 2005) during processes of supplying, transporting, distributing, processing, producing, consuming, disposing and reintegrating natural ecosystems.

The study of energy flows allows us to know the amount of work that the urban system is capable of performing (Haberl, 2015). Energy allows physicochemical systems to maintain themselves and increase their potential information (Margalef, 2002). The second law of thermodynamics or law of Exergy [5] (Shaub & Turek, 2011) affirms: The energy that flows and transforms into the systems loses all capacity to recover in its initial form before any change that occurs. This law indicates that the "*entropy always increases in any irreversible process that occurs spontaneously"* (Margalef, 2002). This law links energy requirement to the complexity of the systems and postulates that highly complex systems require a greater amount of energy to sustain themselves.

Different researches aimed at the study of energy flows in urban ecosystems (Ludwig et al., 2003; Moffatt, 2010; Shaub & Turek, 2011) are employed to coordinate efforts at local, regional, national and global levels for the purpose of conserving energy, developing alternative sources, limiting pollution and mitigating climate change (International Energy Agency, 2017).

On the other hand, the flows of materials have been deeply investigated by Brunner (P. H. Brunner, 2002; P. Brunner & Rechberger, 2005) and supported by systems of indicators and methodologies such as EUROSTAT (Eurostat, 2001). These constitute a tool of analysis that allows the accounting, monitoring, management and conservation of the resources in the society and the environment.

[5] Exergy is the maximum amount of work that can be obtained from matter in contact with its environment. (Shaub & Turek, 2011). The second law of thermodynamic has become an important tool to identify the locations of energy degradation in a process.

This tools also allows the measuring of magnitudes and the locating of specific elements with environmental relevance.

The matter and energy in cities flow from their surrounding areas or distant systems through exchanges and internal circulation between the productive, economic, industrial and natural systems. Once transformed by the urban ecosystems, a part is configured as emissions, dumping and residues and the other part is reintegrated through recycling, reuse or reuse for solid wastes punctually. In either case, with time this matter and energy transformed is accumulated in the city or absorbed by the external systems (Álvarez, 2014), resulting in the limitation of the environmental goods and ecosystem services. However, by promoting the need for efficiency in matter and energy flows, it is possible that the city persists in time and would be sustainable.

The balance of matter and energy are developing in separate research lines but as a whole are complementary because their simultaneous study allows a complex understanding of the metabolism of societies. (Haberl, 2015)

As earlier pointed out, the analysis of flows of matter and energy constitutes a base tool and starting point for analysing urban metabolism (Zhang, 2013). However, research, adaptations and a great number of theoretical approaches for their study have been developed all over the world.

2.1.4 **Methodologies for Metabolic Profiles Construction**

Currently, the studies of metabolism in cities focus on the analysis of trends and transitions at different stages of the development of the city, developing systems of classification and identification of metabolic profiles for the urban areas (Rosado & Kalmykova, 2016).

Different approaches have been defined according to their application field ranging from industrial, social, rural, agrarian or urban metabolism. At the local level, the study of rural or agrarian metabolism focuses on the process of appropriation. In other words, it presents detail of the ecological and economic interrelationships of local natural resources between the local community, the municipality or a rural region and its social environment, understood as the mercantile sectors with which these interrelationships are carried out in a specific territory (Toledo, 2008).

Also according to its purposes and theoretical approximations, other kinds of methodologies have been developed. For instance, as was described in Chapter I, the *Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism* (MuSIASEM) is a metabolism analysis tool whose theoretical development relies heavily on complex adaptive systems theory and its objective is integrate criteria as nested hierarchies, unpredictable loops and a multiple operation scale for the analysis (Giampietro, Mayumi, & Ramos-Martin, 2008).

Other tools are input and output calculations based on Black Box Analysis, Emergy[6] Analysis (Odum, 1996; Zhang et al., 2008) and Material Flow Analysis (MFA) which will be defined in the subsequent chapters of this document.

According to information availability and indicators, other methodologies were developed such as EUROSTAT also known as economic wide material flow analysis for environmental accounting and reporting in European Nations. It is based on a variety of indicators and databases to describe the material flow of economies (Eurostat, 2001).

Other monitoring and assessment methodologies is the Ecological Footprint defined as: Unique (integrated) and descriptive index that shows how many hectares of nature are needed to supply the productive processes and to absorb the waste generated by an economy (Guerrero & Guiñirgo, 2008). These researches developed the calculation of the requirements of urban metabolism in the city of Tandil, Argentina based on the Ecological Footprint indicator. They made an independent calculation of the Ecological Footprint of food consumption in the city, which turned out to be more than half of the total Ecological Footprint of the city (56.3%), corresponding to the large area necessary for the production of food especially meats. However, the study also highlighted the limitations of the Ecological Footprint indicator, mainly because the variables considered are not enough to explain the processes of ecosystems appropriation. Specifically, it does not take into account important ecological impacts such as the consumption of water or the extractive activity of natural resources. In addition, energy consumption focuses only on CO_2 emissions, and finally, it does not account for energy consumption for the processing of consumed items.

Garcia Serna, Morales Pinzon, & Guerrero in 2014 developed an analysis of water flow in cities from the perspective of Urban Metabolism. This study addresses the metabolism by identifying the inputs and outputs of water resources in the metropolitan area of centre west in Colombia. They made a compilation of different studies that quantify water flows. Despite the importance of the analysis of water flows as a fundamental element for the sustainability of urban areas, the approach from the Urban Metabolism is limited just to making a study under a linear system of water supply, distribution and consumption (Garcia Serna, Morales Pinzón, & Guerrero, 2014).

Recently, there have been benchmark analyses between countries and the impacts on ecosystems are now been assessed using indicators such as Ecological Footprints and Input and Output Flow Models (Garcia Serna et al., 2014; Reina, 2013). However, in these studies the concept of Urban Metabolism is reduced to the calculation of inputs and outputs, isolating complex and systemic relationships within the entire metabolic process (Toledo, 2013).

[6] Emergy: It is calculated as the energy contained in the material flows. It is the energy, information or mass of a material flow multiplied by the solar transformation value (Zhang et al., 2008). The emergy takes into account different forms of energy and resources, where each of the forms of energy is produced through processes of transformation in nature, and has a certain capacity to carry out work, in ecological systems as well as Human (Odum, 1996).

Another methodology used for representing the metabolic profiles is the Life Cycle Analysis (LCA). It has been standardised by the International Standards Organizations through the ISO 14040/14044 norms (The International Standards Organisation, 2006). This method assesses the environmental aspects and impacts of a product or service throughout its lifecycle, including the acquisition of raw materials, production, marketing, transportation, distribution, and final disposal. LCA is defined as the phase of cycle life assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle.

Finally, depending on the research objectives, other methodologies emerge such as the methodology from the geography science which allows analyses based on GIS. Another from the social sciences analyses based on socio-ecological systems or in the Human needs specifically, and others from the economy is based on the analysis of economic flows. A clear example are models focused on making inventories of GHG in studies on climate change, inventories and storage of materials such as phosphorus, nitrogen, biomass, nutrient flow analysis, fuels, building materials, solid waste, water and food (Satterthwaite, Satterthwaite, Haughton, Budds, & Dodman, 2008. Soto et al., 2016).

For the development of this work, it was determined to use the MFA methodology (Material Flow Analysis) as detailed in the Chapter I. It is defined as a tool to quantify the flows and stocks of materials in arbitrarily complex systems (P. H. Brunner, 2002). The MFA seeks mainly to define and evaluate in quantitative terms a system of flow and stock of materials, reducing to the maximum the complexity of the system to allow decision making in the administration of resources, and environment and waste, based on the understandable, reproducible and transparent information. The equation for the MFA is: Inflow + Net production = Increase in the storage + Outflow

2.1.5 **Metabolism in Latin America: Social Metabolism**

The complexity that drives economic growth in emerging economies such as Brazil, China and India is one of the pillars of global metabolism. These economies are growing by leaps and bounds, but unfortunately, they are also leading the increase of extractive industries in Latin America (Martínez-Alier,2003), endangering ecosystems such as mangroves, reefs in the Amazon rainforest, to mention just a few. This situation is also violating the traditions and the territory of indigenous communities in Central and South America.

The cheap importation of raw materials from the so-called agrarian countries, the low cost of labour, the "free" exportation of CO_2 to the oceans and the atmosphere among other factors, characterising this economic development, are leading to an increase of ecologically unequal trade (Walter A. Pengue, 2002).

Analysis of these social phenomena appears concepts such as ecological economy, environmental justice, the circular economy or industrial ecology, all of which attempts to forge a path for an economically, socially and environmentally viable development.

These concepts have some common premises such as conversion of outputs from a process to be used as inputs for other processes where alternatives for the reduction of energy consumption are taken into account (Haberl, Fischer-Kowalski, Krausmann, Weisz, & Winiwarter, 2004). Nevertheless, these are global trend to replace or increase the consumption of oil and electricity, the construction of hydroelectric plants or the implementation of sustainable energies that function as substitute sources, but not as strategies for reducing the energy consumption (Joan Martínez-Alier & Muradian, 2015)

These ecologically unequal economic exchanges are governed by the economic bases, where the economy is open for energy and materials entry and the exit of waste and heat dissipation. In this light, Joan Martínez Alier established from the ecological economy approach that *"suppressing unequal exchange within society (social crisis) is the only possible way of suppressing unequal exchange between society and nature (ecological crisis)."*

Within the study of ecological and the industrial economy, the term Social Metabolism is developed as a tool for its application. Marina Fischer-Kowalski in her 1997 book: Handbook of environmental economy, presents the term of Social Metabolism as "*a particular form in which societies establish and maintain their material input from and output to nature; defining it as the way in which societies organize the exchange of matter and energy with their natural environment"* (Fischer-Kowalski, 2011).

This way, Social Metabolism is presented as a perspective to analyse the relations between society and nature from its material bases, mainly through the study of mater and energy flows. Another important aspect that Social Metabolism takes into consideration the information flows (Toledo, 2013).

With respect to energy flows, Social Metabolism is based on Fischer-Kowalski in the study of the exosomatic and endosomatic flows as mentioned earlier (González de Molina & Toledo, 2014). However, reflecting on these, Giampietro 2012 stated that the endosomatic flows of metabolism remain constant over time and particularly when considered per capita, these flows are directly related to the size of the population. On the other hand, exosomatic flows are highly variable and depending on the capacity of technological capital in society, their distribution is usually heterogeneous through the different elements that are distinguished within society (Giampietro, Mayumi, & Alevgiil H, 2012).

At the same time, in Latin America, the researcher Víctor Toledo, was further investigating on the processes that underlie the Social Metabolism (Toledo, 2013) *(Figure 6)*. He affirms that human societies under whatever conditions or levels of complexity, do not exist in an ecological vacuum, but they affect and are affected by the dynamics, cycles and pulses of nature.

This phenomenon, according to Toledo (2013), implies a set of processes through which human beings organised in society, regardless of their situation in the space (social formation) and the time (historical moment). Those processes include appropriating, circulating, transforming, consuming and they discard matter and/or energy from the natural world (Barrera-Bassols & Toledo, 2008)

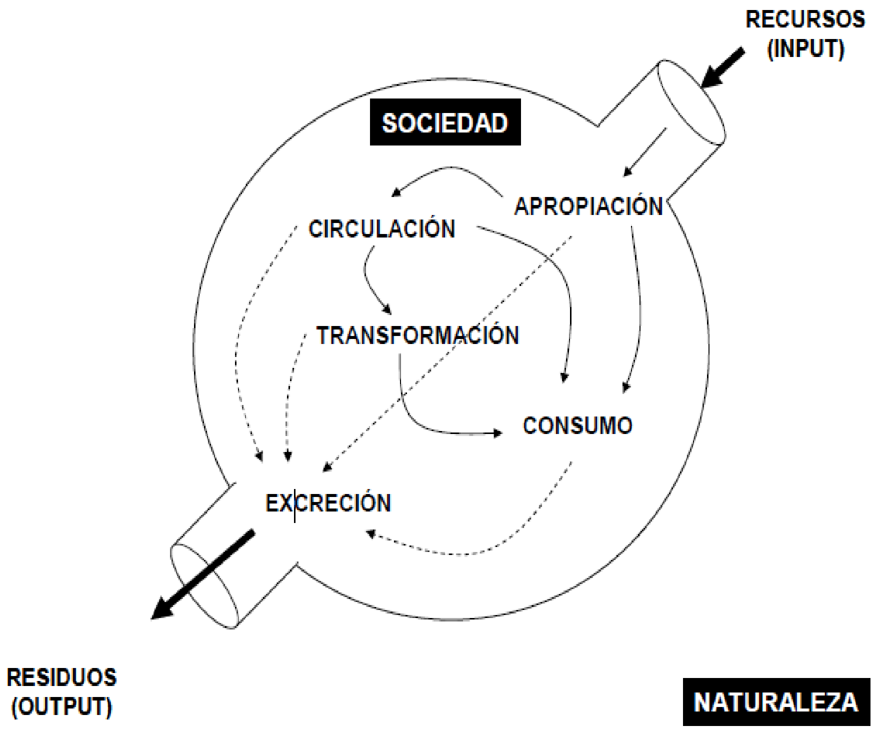


Figure 6: Social Metabolism Model by Victor Toledo
Source: Toledo, 2008

As stated above, social metabolism takes into account two scales applied in its study. The timescale; which is fixed to Rural, organic or agrarian Metabolism, the Industrial Metabolism and The Urban Metabolism (González de Molina & Toledo, 2014; Wiedenhofer et al., 2013). On the other hand, the geographical scale comprises of analysis conducted from the Local Metabolism to the Global Metabolism as well as Regional and National Metabolism. It is also called the Trans-Scalar Metabolism.

From the time scale analysis, Social Metabolism is based on the science as a whole that must know the past, in order to obtain lessons from it and for adapting to rigorous historical perspective allowing for understanding of present situation in a comprehensive way.

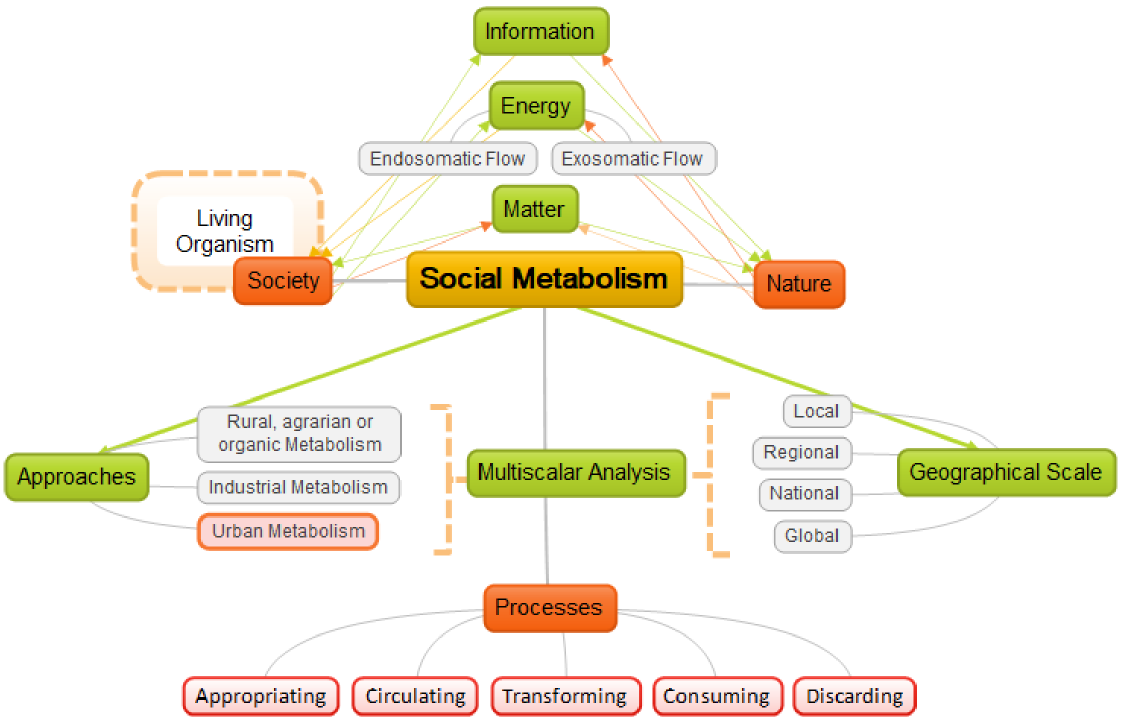


Figure 7: Social Metabolism Conceptualization
Source: Own elaboration based on González de Molina & Toledo, 2014

The concept of social metabolism is one of the more robust instruments of the past two decades to understand the complexity of the present *(Figure 7).* In Latin American stages, this concept has aroused interest mainly in countries such as Spain, Mexico and Brazil, where according to studies by González de Molina and Víctor Toledo in 2007 (González de Molina & Toledo, 2014), researches and investigations in Spanish and Portuguese languages have increased significantly. This situation is probably given by the relevance which gives this concept to intangibles dimensions as: culture, knowledge, ideology, institutions and the cosmovision in the analysis (Reina, 2013).

The contributions of the social metabolism of Latin America to the global social metabolism are growing. However, behind this reality is the problem of environmental degradation and pollution at different geographical scales. The growing need implies one of the main challenges in terms of sustainability (Giampietro et al., 2012; Haberl, Fischer-Kowalski, Krausmann, Martinez-Alier, & Winiwarter, 2011)

2.1.6 Scale Debate

As it was shown in the previous chapter, the metabolism that illustrates the relationships between society and nature can be analysed from different approaches or scales.

Initially, the social metabolism defines as dimensions or approaches to: Rural Metabolism, Urban Metabolism and Industrial Metabolism, which can be analysed in different geographical scales: Local, Regional, National or Global and these in turn can also be analysed in different periods of time throughout history called as Metabolic Eras, where three stages are identified within the humans evolution, starting from them role as hunters-gatherers where starts them interaction with the nature, then the era of farmer, or more ahead, the era of intensive exploitation of natural resources for industry.

These different scales, approaches, dimensions and eras provide to the metabolism analysis its systemic capacity, where it is possible to perform a multi-scalar analysis, identifying the relationships between the different elements in the system in several scales, which increases its complexity and collaborates to the understanding of the purposes of the system.

Within the first steps in thesis work process, was difficult to define whether the study of food flows was presented under a social metabolism, an urban metabolism or a rural metabolism approach, and it was one of the challenges. Given that, according to the purposes of the study it was necessary to carry out an in-depth analysis of the characteristics that share the concepts and the closeness of its application with the objectives set.

Taking into account the objectives of this thesis work, this paragraph emphasis on the urban metabolism and its relationship with the rural and industrial metabolism, focused on the local and regional geographic scales, without ignoring its relevance at the national and global scales.

As evidenced throughout this chapter, the urban metabolism studies the relationships between city and nature, on the other hand, the social metabolism studies the relations between society and nature, each one seeing the city and society as living organisms. Social metabolism is based on that the laws that govern the behaviour and evolution of living organism also are applied to human societies, and the Urban Metabolism identifies the variables of dependence on the external environment and the relationships and interconnections between the elements that set up the city within material and energy flows to affirm also that cities are dynamic organisms.

The urban metabolism illustrates the conversion of natural resources into products and waste in the same way that occurs with human metabolic processes and ecosystems. Currently, urban metabolism has extended to the inclusion of human perspectives where socioeconomic aspects of sustainability are integrated with the environmental dimension (Zhang et al., 2006). What puts again the metabolic analysis within other scales, the scales of sustainability: economic, social and natural.

Local Metabolism, which can be approached from an analysis of the rural and urban metabolism as well, given their important interaction at the local level, however, it is necessary to specify at this point What this thesis work refers with the term “local”.

This work considers the local level as it is addressed in studies of food security (Feagan, 2007). According to DeWeerdt, Local is a radius of 100 miles or 160 Km approx. which is considered the necessarily large to get to a city and nearby necessarily to be considered local (DeWeerdt, 2011).

Moreover, rural metabolism, studied on this scale was defined by Víctor Toledo (Toledo, 2008) as "All acts through which society takes possession of goods and services of nature". In this concept is deepened in the ecological and economic analysis of the appropriation phenomenon, through an interdisciplinary analysis and multi-scale model that integrates monetary flows, work, matter, energy, goods and services. Considering that the rural social space consisting of a set of units of appropriation.

The rural population[7] in general terms is presenting major migration to the city, that mainly due to the search for job opportunities and income offering by cities and also the lack of interest and support in family farming by Governments Besides that, the social conflicts which affects mainly rural areas causing this shift. The next graphs *(Figure 8,9).* show the proportion and historical evolution of rural and urban population in Brazil:

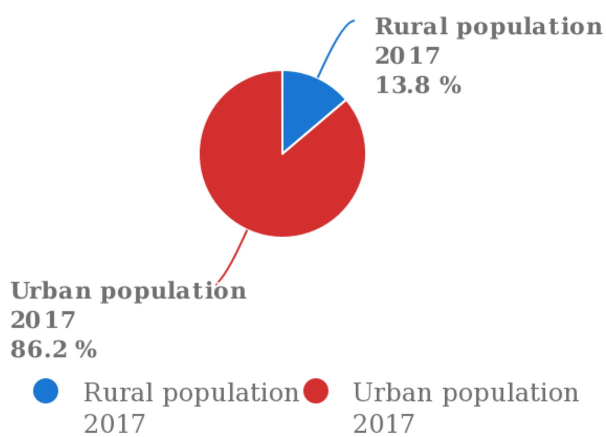


Figure 8: Rural and urban population in Brazil 2017
Source: FAOSTAT, 2018

[7] Rural population is one that depends on agriculture, livestock, hunting, fishing, extraction and collection for their subsistence.

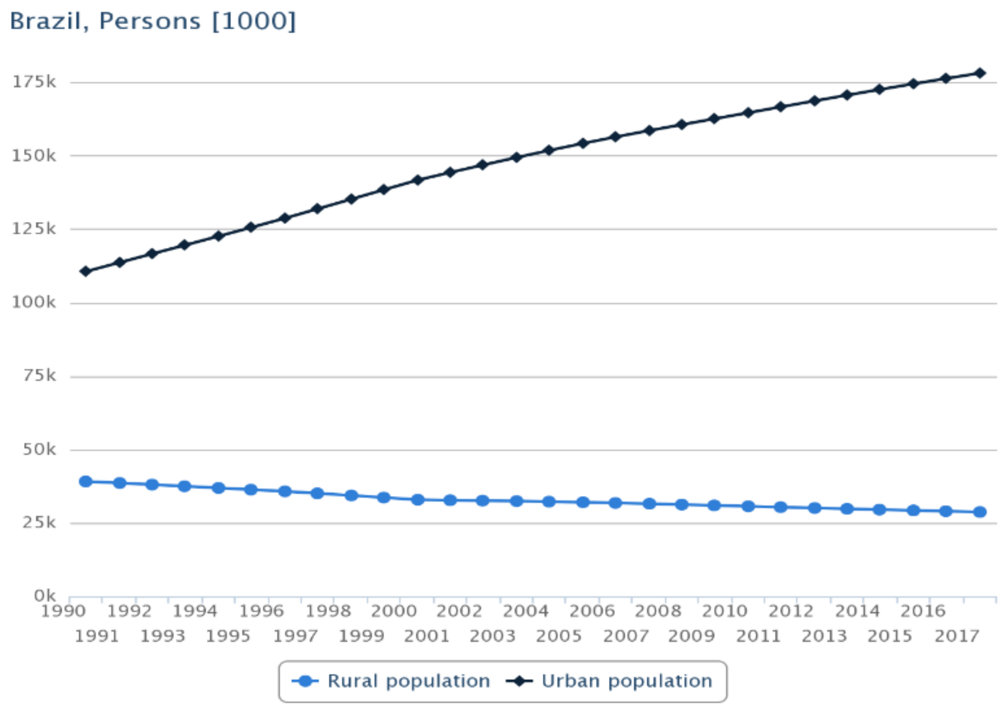


Figure 9: Rural and urban population in Brazil trend 1990-2017
Source: FAOSTAT, 2018

Another scale taken into account in the analysis of urban metabolism, is metabolism of industries, or industry metabolism, which presents analysis of the flows of materials and energy in industrial systems or companies. This analysis focuses particularly in the processes of transformation. Industrial Metabolism is the conceptual basis in industrial ecology (Díaz Álvarez, 2014) and its main methodology is the life cycle of the product.

From the perspective of the social metabolism, it is also possible to demonstrate the ideological and strategic influence that industrial agriculture has in food self-sufficiency policies in Latin American countries or over the production of biofuels, where there is a high energy cost to maintain and rewarded with an accumulation of geopolitical power(Fuente Carrasco, 2004).

Victor Toledo made an important approach to the relationship between the dimensions rural, urban and industrial metabolism and its interaction with metabolic processes defined within the framework of social metabolism. *(Figure 10)*

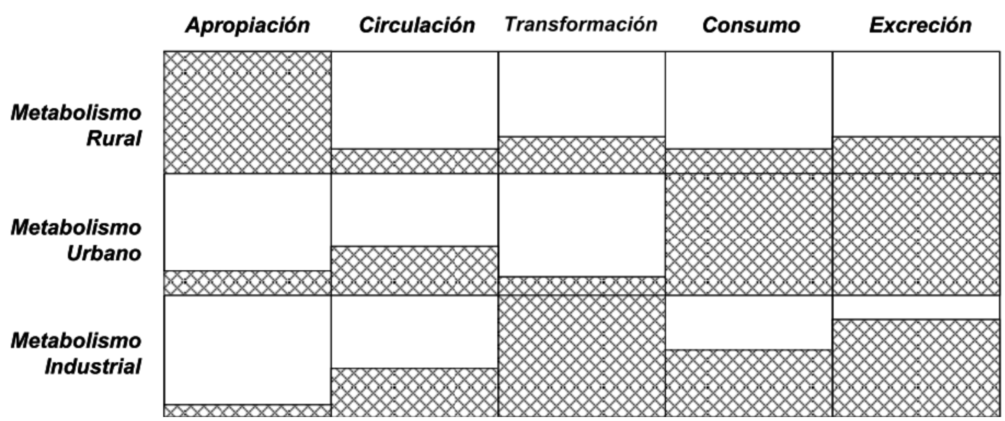


Figure 10:Relationship between metabolic process and social metabolic dimensions
Source: Toledo, 2008

In this representation, it is possible to observe the focus of each metabolism dimension, which are discussed in this work at the local level. Rural metabolism focuses on the processes of appropriation of the goods and services of nature as described earlier. Urban metabolism focuses on the consumption and discarding processes while industrial metabolism focuses mainly on the transformation processes impacting significantly on the processes of waste.

The food system operates on multiple scales, from the global scale or the international market to cellular levels of nutritional consumption or individual metabolism (Brinkley, 2013). The lines that follow introduce the second key concept in this research work; the foodshed assessment, carrying out a first count of the general content of food security in the world.

2.2 Food Security

The concept of food security refers *"to access by all people, at all times to enough food for an active and healthy life"* (Hedden, 1929). This concept was ratified by the World Food Summit in 1996, where Food security is further explained as: "*when all people, all times have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"* (Food and Agriculture Organization, 1996).

According to 2017 report of the Food Agriculture Organisation of the United Nations, the global current food production is enough to feed everyone in the world. However, 815 million people suffer from hunger (Food and Agriculture Organization of the United Nations, 2017). *Figure 11* represents almost seven times more than the total population in Mexico and ten times the population of Germany.

Situations of social, political and economic conflict, violence, access to natural resources, displacement, economic slowdown caused by political decisions, weather conditions like drought, flood, the phenomenon "El Niño" o "La Niña", significantly worsens the global hunger situation. This is mainly in areas or rural communities where livelihoods depend largely on agriculture, negatively impacting the availability of food from production, collection, processing, and transport to the supply of inputs, financing and marketing.

Number of people undernourished in the world 2000-2016

Figure 11: Number of people undernourished in the world 2016
Source: Food and Agriculture Organization of the United Nations, 2017

Other factors that influence Food security, not only on the global scale include education, the resources assigned to policies and programmes of nutrition especially for mothers, infants and children, access safe drinking water, basic sanitation, access to the health services, lifestyle, consumption of highly processed foods and cultural influences.

In light of this, the global challenge in the field of food safety and food access is huge. The first focus was on reducing malnutrition in the populations, where malnutrition refers to both undernourishment usually in children and obesity usually in adults. The second challenge is related to physical conditions generally with respect to infrastructure and economic conditions related to the price, allowing the access to food.

FAO reports that 154.8 million children under ages of 5 years suffer from chronic malnutrition, which is translated to growth retardation, and 640,9 million adults suffer from obesity on a rising trend. In Latin America, about one-quarter of the current adult population are considered obese. This situation is related to poverty, where the price for buying nutritious food is very high making the people opt for consumption of cheaper foods which are generally less healthy and hyper-caloric, generating conditions of obesity. This is in addition to other issues such as preferences and marketing.

Another important aspect that worsens the global food crises are social conflicts and internal wars in the countries which have increased by 125% since 2010 (Organización de las Naciones Unidas para la Alimentación y la Agricultura; & Organización Panamericana de la Salud, 2017), severely affecting severely the food production systems. Countries such as Colombia, Yemen, Syria, Sudan or Lebanon suffer the consequences of the conflict over their traditional systems of food production. *"The poor tend to be the most affected by the conflict when the State, socio-economic systems and communities lack the capacity to prevent it, avoid it, or manage it*" (Food and Agriculture Organization of the United Nations, 2017).

Closing the curtain on global food crises is the rising trend of food wastage which is the foundation on which this study thrives *(Figure 12)*. **FAO reported in 2017 that one-third of food produced for human consumption is lost or wasted globally[8].** This means that in the sustainable dimension, huge amounts of natural resources used for food production such as water, energy, land, biomass, fertilisers, etc., are used in vain as well as the greenhouse gases emitted during the food flow from production to the consumption.

[8] Food losses refer to the decrease of eatable food for human consumption throughout a part of the supply chain, it takes place at production, postharvest and processing stages in the food flow. Food waste occurs at the end of the food chain, retail and final consumption, which relates to retailers' and consumers' behavior. Both concepts are including in Food wastage term.

Per capita food losses and waste, at consumption and pre-consumptions stages, in different regions of the world (kg/year)

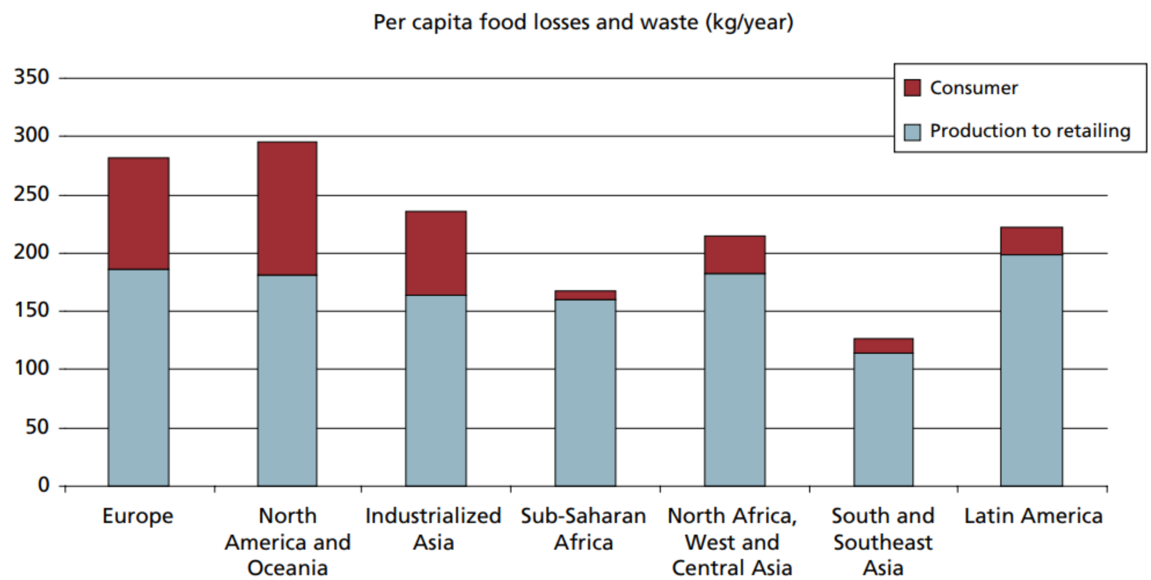


Figure 12: Per capita food losses and waste
Source: Food and Agriculture Organization, 2011

Food is wasted throughout the food flow from initial agricultural production to final household consumption. According to the FAO, food waste in industrialised countries occurs in the last processes of food flow. This coincides with processes of marketing and consumption, where food discarding is done even before its expiration date or when can be regarded as still suitable for human consumption. In Africa and Latin America, the waste of food usually occurs during the production and transportation, given the inefficiency in harvest and cooling systems.

However, it is important to highlight the global efforts for the evaluation of food waste. A possible example is the Commission for Environmental Cooperation- CEC between the USA, Canada and Mexico, who in May 2018 integrated a group of experts for the efficient measurement of loss and waste of food in these countries. Their objective is to provide a guide for the measurement of loss and food waste to serve as a tool for awareness, education, prevention, and decision-making at the political level on food security, economy and sustainability (Commission for Environmental Cooperation, 2018).

In relation to food security, recent methods have evolved that encourage local consumption. For example, fairs by farmers, craft or organic producers (Lea, Worsley, & Crawford, 2005), which are mainly supported by institutions or Government offices and legally regulated to ensure fair trade between producers and consumers.

Other alternatives such as "Pick your own"; where the consumer is permitted to go inside the crops and to participate in the collection of food, saving costs of marketing and harvesting, are awakening great interest (Tippins, Rassuli, & Hollander, 2002). Other methods are linked with local economic development, such as agriculture supported by the community where consumers can buy bonds on the production including urban agriculture (Dimitri, Oberholtzer, & Pressman, 2016), are also presented as opportunities for sustainable food security at the local level.

2.3 Foodshed Assessment: Conceptualization and historical evolution

Today, most of the urban areas are supported by a foodshed *(Figure 13)* Among other resource flows, such as water, energy and materials, the issue of the reliable food supply as a means of attaining urban food security is of particular interest for community planners. The development of the foodshed assessment allows the geographic location of food flow in an ecosystem as an analysis tool that also allows the identification of loss or waste of food in addition to the display of access, the quantity and quality of food constituting food security.

A foodshed is presented as an analogy of the watershed[9]; the "headwaters" of the foodshed are the food producers: farmers, ranchers and fishermen. The "tributaries" of the foodshed are food distribution mechanisms, grocery stores and shipping lines. The "discharge area" of foodshed is the consumer. This image of tributaries that flow into the rivers helps to connect the often disparate parts of a food supply for the purposes of local and regional planning (Fradkin, 2015). A watershed identifies the flow of water that drains to a particular place. A foodshed reflects the flow of food that feeds a particular population.

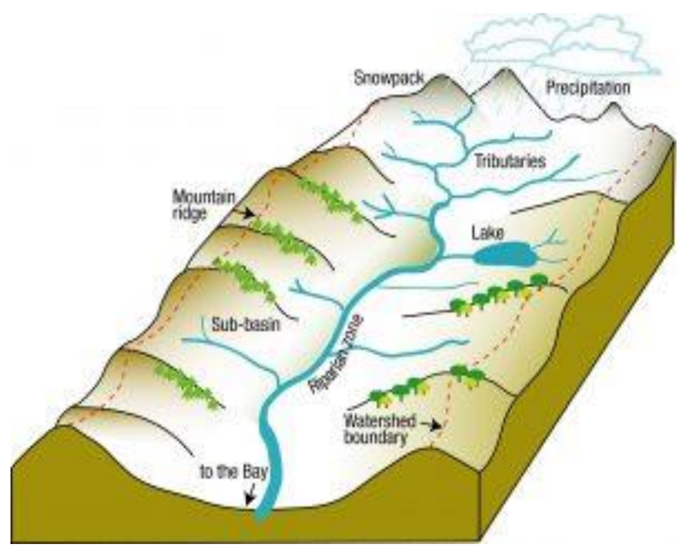


Figure 13: Watershed scheme
Source: http://thewatershedproject.org

The "foodshed" concept was originally used in 1929 by W.P. Hedden to describe what he observed as the "gigantic traffic" of the food system: the trucks, ships, and trains that transport food from the countryside to the city (Hedden, 1929). He later established the comparison between a foodshed and a watershed, an area of land drained through a common point *(Figure 8)* then added to this concept geographic, social and economic dimensions. Hedden highlighted that the limits that determine the flow of raindrops in a watershed are the elevations of the earth - its topography,

[9] Watershed is the area of land that drains rainwater into a common body of water such as a creek or bay. *http://thewatershedproject.org*

while in a Foodshed these limits that guide and control the food flows are more social and economic than physical.

Later in 1991, Arthur Getz associated this term with "permaculture" in his research on *Urban foodsheds on permaculture activist*, to explain the functioning of food systems and highlight the need for their protection (Peters, Bills, Wilkins, & Fick, 2009).

The size of a Foodshed depends on different variables such as climatic patterns, types of soil, water availability, topography, labour, infrastructure, among others that must be taken into account in a Foodshed Assessment (Feagan, 2007). A Foodshed Assessment can be performed for a particular type of food or for all foods perceived by a community.

Studying foodsheds is currently a major field of food system research. In particular, it is increasingly acknowledging that urban consumption centres benefit from being connected to their peri-urban and rural agricultural production areas within a wider territory.

A foodshed assessment serves as a planning tool for land use planners, as well as for local food advocates. It answers the question *How much the agricultural production in a specific area (country, region, city, community) satisfies the food consumption needs of the area population?* It also compares the amount of current working farmlands to open lands available for farming as well as the extent of farmland necessary to meet regional food demand for various diet types. This information is very relevant for a formulation, planning and development of a food security program.

Hence, it is possible to affirm that the foodshed assessment is a tool for the food security. In a local context, many benefits can be obtained by the foodshed assessment in order to preserve food security. Nevertheless, a foodshed assessment can also be done on different scales: local, regional, state, national and even global. The main concerns related to food security, where the foodshed assessment could be useful are:

- Reducing transportation and energy needs: The food displacement from its origin to the consumer's table derives not only in environmental problems such as GHG emissions but also extensive costs and high energy consumption, particularly by refrigeration systems and imported food (DeWeerdt, 2011; Peters, Wilkins, & Fick, 2008). However, the environmental impact in this sense cannot be measured only in the distance that food travelled, but also by evaluating how it was transported (by train, plane, boat, truck, etc.) and how it was cultivated (fertiliser use, seed management, pesticide use, greenhouses, monocultures farms, etc.) (Tichenor, Peters, Norris, Thoma, & Griffin, 2017).
- Improving nutrition and health: The local products are usually vegetables, fruits, grains, meats and dairy products. Generally, the products inside a foodshed have a better

nutritional content and better taste as compared to processed or imported products which are typically marketed by supermarkets (El-Abbadi, Peters, Griffin, Nelson, & Jacques, 2017; O ’Hara & Pirog, 2013).

- Advancing Eco-agricultural practices: The foodshed assessment allows to identify the forms of production in the region. These can be the industrialised type of conventional agriculture or with the implementation of agro-ecological practices (Francis & Wezel, 2015). For the first two cases, it is possible to establish programs that reduce soil erosion, the use of fertilizers and the irrational use of water, allowing progress towards agro-sustainable practices which are focused on food production and integral food systems. Currently, it is the main base for conceptualising and implementing responsible and sustainable agricultural change. The agro-ecology as a concept has been developed in response to awareness of declining resource availability and negative impacts of conventional chemical agriculture on the environment.

- Enhancing the local economy and competitiveness: Money circulation improves regional micro-economy within the foodshed. The money which is obtained by the producer is re-invested in local markets or stores alongside the promotion of employment in the region with reduced production cost (Halweil, 2002). With regards to competitiveness, it is also necessary to take into account that technological developments and growing innovation in refrigeration and food preservation systems prolongs the lifespan of food as well as increase the distribution distances. On the other hand, they increase the production costs significantly and represent a potential risk in food quality which is translated to the health of consumers (Pirog & Mccann, 2009).

- Fostering community interaction and social networking: The participation of the community, its cohesion power synergy and role as decision-makers is indispensable in the success of food sustainable systems. The food exchange locally produced, strengthens relationships between community members enhancing social participation. Additional local production supports allows the development of communication networks which play an important role in developing food security programs (Murphy, 2008).

- Protecting local farms and farmers: An area where food needs are supplied by their foodshed guarantees its permanence over time, as long as the production practices are sustainable. A food security program focuses on maintaining a foodshed and protects both farmers and farms (Halweil, 2002; Martinez et al., 2010; O ’Hara & Pirog, 2013).

- Preserving food safety for food security: The management and prevention of food contamination is easier if food flow is identified. Currently, when a contamination case occurs, it is often difficult to identify throughout the entire chain supply exactly where and how the contamination occurred (King et al., 2017).

As identified above, food security and access for all people to healthy foods is a growing concern among community planners.

A foodshed assessment allows planners to further understand food needs and the ability for self-sufficiency. It provides tools for understanding and protecting farmland as a critical local resource as well as avails planners access to more data for land use decisions and food security programs.

The foodshed assessment in relation to food security has not been extensively discussed under these concepts. However, the notion of food self-sufficiency, referring to the ability of cities, regions and countries to obtain required alimentation within their boundaries is always a concern in the development plans.

Cities, such as London, Toronto and Belo Horizonte (Blay-Palmer, 2009; Reynolds, 2009; Rocha & Lessa, 2009) have intensified food planning and policy efforts to foster local food systems and connect urban centres with foodsheds. However, for effective policy design and governance, an adequate information data and knowledge base is needed to effectively plan food system production, processing, distribution, consumption and infrastructure development.

2.4 Relationship between Urban Metabolism and Foodshed Assessment

While developing this chapter, it was possible to establish the conceptual framework for this research work as well as introduce the Urban Metabolism concept based on Systems Thinking approach, as a tool for identifying matter and energy flows in urban ecosystems. Urban planners use this instrument for the development of sustainable cities. Likewise, the Foodshed Assessment as a tool of urban planning and for the geographic identification of food sources for cities and the promotion of local food systems has been established. The question now is at what point do these two concepts converge?

As affirmed by Víctor Toledo, eating the food we produce allows an equivalent exchange between the goods and services that we extract from the ecosystems and the appropriation units, (Toledo, 2008) which is considered an indispensable requirement for a sustainable food system. Currently, food wastage is a concern at local, regional, national and global levels.

FAO reports that in 2013 a third part of the world food production for human consumption is lost or wasted every year during the production, distribution, and processing flow, which means 1.3 billion tonnes per year (30% World food production), enough to feed 3 billion of people, which in economic terms represents USD 750 billion annually (Food and Agriculture Organization of the United Nations, 2013)

Food wastage is an issue that concerns everyone; as individuals, communities, societies, citizens and as humans. The use of natural resources, energy, water, land, in addition, to the pesticides, genetic selection, chemical fertilisers, intensive exploitation in monocultures and intensive agro-industries, during the process of production, transport and marketing of food for consumption is leading the planet to limits such as the global environmental change. According to FAO, agricultural production contributes about 14% of anthropogenic greenhouse gases emissions, doubling it figure in the last five decades (Food and Agriculture Organization of the United Nations, 2015). This is because the amounts of natural carbon contained in forest or shrubs is oxidised and released into the atmosphere during the deforestation for its agricultural exploitation. This is in addition to direct CO_2 emissions from fuels used for food transportation and distribution around the world.

With this concern raised, the food flow is addressed as one of the flows studied by the urban metabolism where it is possible to identify the processes of appropriation, circulation, transportation, distribution, consumption and disposition of food through one of the methodologies offered by the study of urban metabolism, which is the MFA. However, as specified earlier, one of its limitations is the identification of the boundaries or limits that determine the study.

Commonly, the MFA determines as boundaries; the same geographical area as the study area. For example, the limits of a city, for the present study, where the food flow does not involve just a single geographical area, it is necessary to resort to other tools that allow boundary identification while preserving the same analysis approach from its complexity for the development of sustainable cities. Here, the Foodshed Assessment plays a crucial role as the tool for this approach and in the most appropriate way because it takes into account the food flow enabling identification of a geographic area that determines the flow. It offers a wise approach to complex environmental issues that require systematic solutions at the community scale.

As described in the previous chapter, the Foodshed Assessment allows an analysis that takes into account a geographical scale for the determination of food flow from the area where food is produced to the place where it is consumed. This includes the land where it was grown, the transport routes and the places where it is marketed, and the entire processes that set up an urban metabolism. Foodshed assessment allows to identify losses and waste along the food supply chain, and it presents potential increase in food systems efficiency. It also provides information about the possibility of satisfying local demand through adjacent agriculture. It also indicates the local critical points of possible future food stresses, which aligns with the objectives of this research work.

The synthesis of this relationship is presented in the model of Food Flows *(Figure 14),* where the interaction of the main processes that defines urban metabolism is initially identified involving economic, social, ecological and technical processes. Within these processes are identified sub-processes that direct the flow of food: production, transportation, consumption and disposal of food and within each subprocess; its constituent elements. At this stage and within the model, the interrelationships nested between systems and subsystems can be easily observed. Determining the boundary within this analysis is given by the foodshed assessment, which defines the geographic area of study. The analysis of urban metabolism in its complexity is in line with the MFA, with the identification of inputs, material stocks such as raw materials, food storage, landfill, and finally, the MFA identifies the outputs of the system.

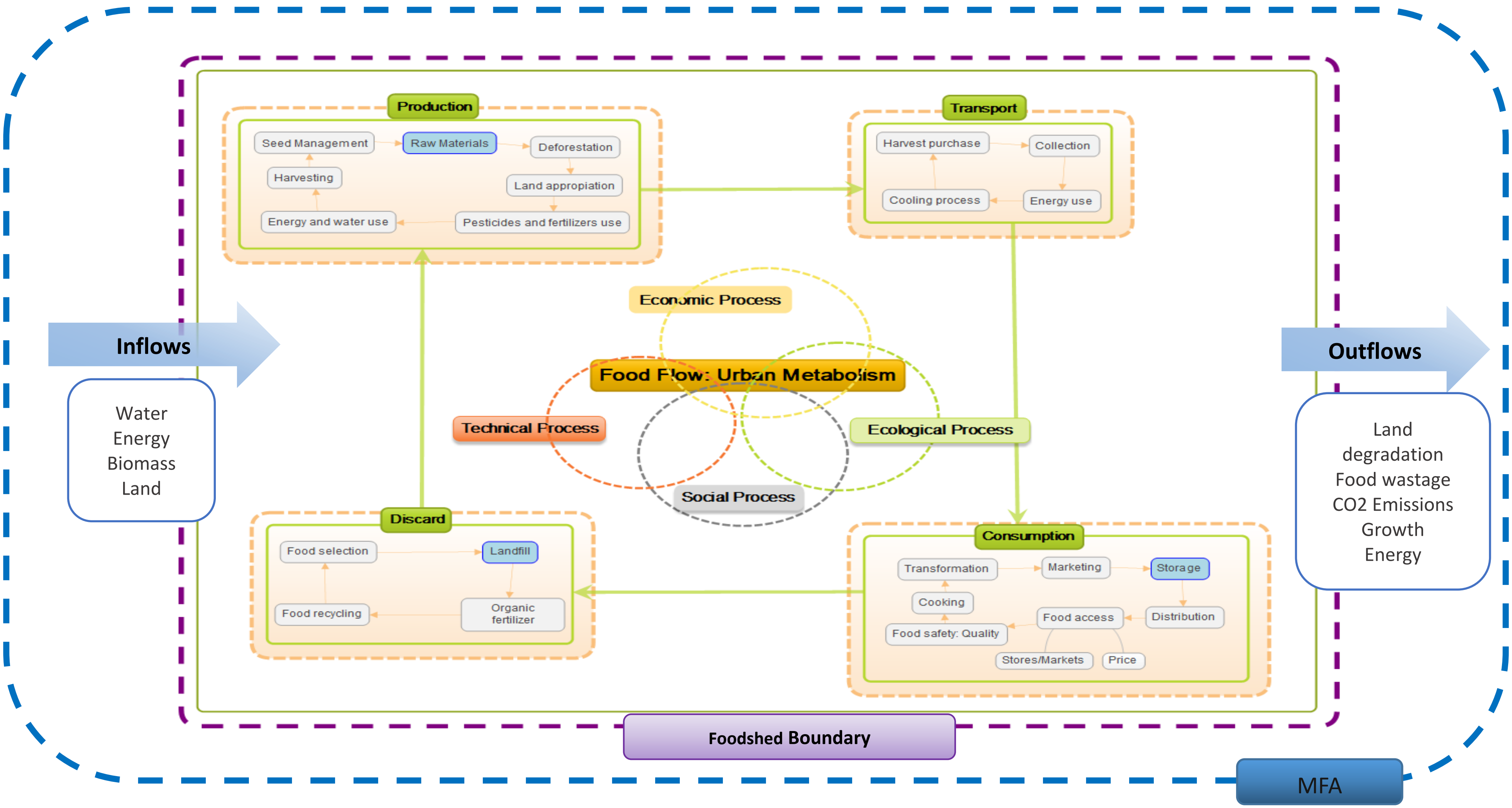
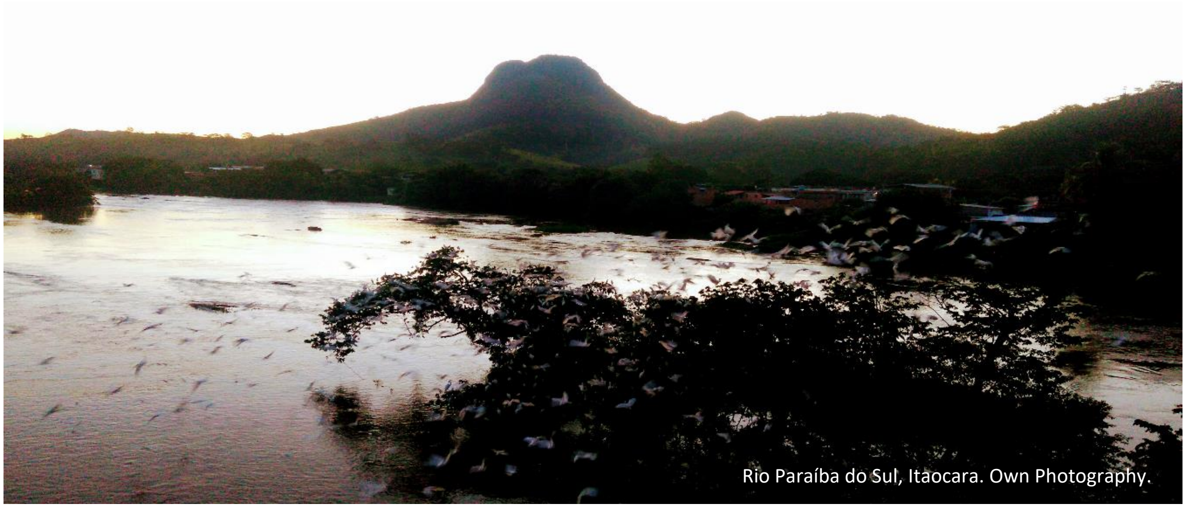


Figure 14: Food flow: Urban Metabolism Model
Source: Own Elaboration

3 Case Study Description


Rio Paraíba do Sul, Itaocara. Own Photography.

"(…) su objetivo era cruzar las montañas en dirección oeste en busca de una salida al mar.… construido a orillas de un río con un lecho de piedras pulidas, blancas y enormes como huevos prehistóricos."
Gabriel García Márquez

This study was conducted in the municipality of Itaocara in the northwestern region of the State of Rio de Janeiro in Brazil.

Selection of this case study was done taking into consideration the research work and cooperation between the Academy and the State. This particular case study is within the scope of the INTECRAL project which was in its final phase at the time of collecting data for this work. However, the support and exchange of information still exist between the concerned institutions. The INTECRAL Project is led by an agreement between several German and Brazilian institutions. For the study in consideration, the institutions involved are RioRural, Emater Rio de Janeiro and Itaocara offices which belong the Government of the State of Rio de Janeiro and TH Köln – University of Applied Sciences. This project aims "To provide integrated solutions of services and technologies to allow an environmental sound and economically sustained development of the landscapes and watersheds supporting small-scale rural farmers in Rio de Janeiro state within the environment of emerging green markets"(INTECRAL-RioRural, 2018).

3.1 Case Study Selection

Within this institutional framework, the selection of the study area was done in consideration with aspects directly related to the food flows in Northwesten Region. It is located in the State of Rio de Janeiro. The Northwesten region is one of the main sources of food supply, mainly milk, vegetables and meat to major cities such as Rio de Janeiro and Belo Horizonte.

The Northwestern Region consists of 13 municipalities, where the degree food production was evaluated taking into account three types of production; MP-Meat production, CP-Crop Production and DP-Dairy Production. The diversity of food production, the number of farmers and the quantity of production is shown in *(Figure 15).* The data is presented in Annex 4. Finally, the municipality of Itaocara was obtained as the municipality where the food flows are more representative.

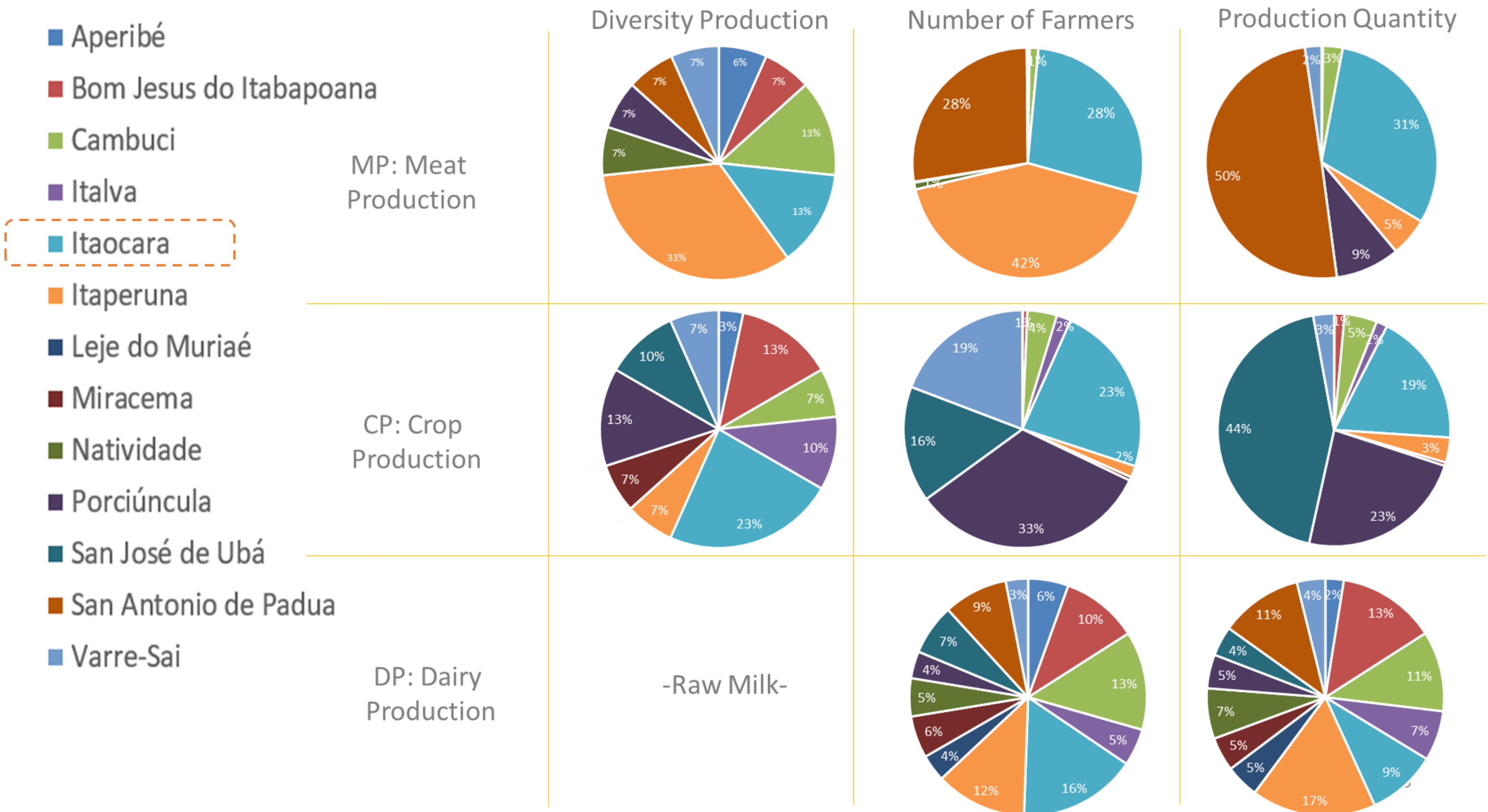


Figure 15: Case Study selection
Source: Own elaboration based on EMATER Database 2015,2016

Municipalities such as Itaperuna also represent important flows in food production. However, they are mainly involved in the production of beef, pork, eggs and to a lesser extent crop production. A similar situation exists in Portiuncula municipality where production is focused on coffee or San Jose de Ubá in tomato production. The municipality of Itaocara presents significant percentages of representation in each of the three types of production: Meat, Crop and Dairy.

3.2 Geographical Context and Localization

The Federal Republic of Brazil is located in the centre of South America, bordering with Argentina, Uruguay, Paraguay, Bolivia, Peru, Colombia, Venezuela, Guyana, Surinam, French Guyana and the Atlantic Ocean. With an area of more than 8.5 million km^2, it occupies 48% of the South American territory being the fifth largest country in the world. *(Table 6)*

Brazil has 26 states, one federal district and about 5.565 municipalities with its capital is Brasilia. The federal states are divided into five geographical regions: Midwest, Northeast, North, Southeast and South. Thanks to its spaciousness and topographical variety, Brazil has a wide variety of climatic conditions, with tropical characteristics in most parts of the country, which corresponds to a wide variety in vegetation, biodiversity and food production.

Table 6: General Information of Brazil

General Information of Brazil	
Total Population (2010)	208.385.000
Population density (Hab/Km$_2$)(2016)	24,8
Annual growth population rate (%)(2016)	0,8
Literacy rate (%)(2015)	92,6
GDP (USD) (2016)	1793,9 Billons
GDP growth (annual %)(2016)	-3,5
Main exported products (2016)	Soybean, Iron, Sugar, Crude Oil, Meat
Main imported products (2016)	Refined Oil, Medicine, telephones, cars
Agro-food exports (USD)(2017)	69.572 Mill
Agro-food imports (USD)(2017)	10.981 Mill
Total physical cultivated area (ha)(2012)	80 Mill
Poverty headcount ratio at national poverty lines (% of population)(2016)	8,7
Forest area (Km$_2$)(2016)	4,9 Mill
Annual precipitation average (1961-2007)	1761 mm
Urban population growth (annual %)(2016)	1.1

Sources: FAO 2012,2016,2017, OEC 2016, World Bank 2016, PNUD 2015, IBGE 2017

The Rio de Janeiro state is in the Southeast region with an area of 43.780 km^2 being the third less extensive in Brazil and the smallest state in the region. It shares borders with the states of Mina Gerais to the North, Espiritu Santo to the east, Säo Paulo on the wast and to its south is the South

Atlantic Ocean. Its capital is the city of Rio de Janeiro, and the state is divided into five regions: Center, Northwest, North, Serrana and South (IBGE, 2018). *(Table 7)*

The Rio Paraíba del Sur, Macaé, Guandú, Piraí and Muriaé rivers pass through the state of Rio de Janeiro. The state has a tropical climate with high temperatures on the coasts and rains in the mountainous regions. The rains tend to be concentrated in summer (December - March) with a dry season in winter (June - September). Precipitation ranges between 1.000 and 1.500 millimetres in a year.

The state is part of the Mata Atlantica biome consisting of two distinct morphological areas; a coastal plain and a plateau, both formed from the coast on the Atlantic Ocean towards Minas Gerais. The territory of the state initially consist of 90% tropical forests, but several portions have been devastated for urbanization and plantations especially for coffee and sugar cane (Bastos, Julia; Napoleao, 2010).

Rio de Janeiro is the second most economically developed state in Brazil next to Säo Paulo (Subsecretaria de Desenvolvimento Econômico RJ, 2018). The economy of the state is based on the production of oil and natural gas. The industrial sector constitutes the largest component of GDP (51.6%), followed by the service sector at (47.8%), while agriculture represents 0.6% of GDP.

Table 7: General Information of Rio de Janeiro State

General Information of Rio de Janeiro State	
Total Population (2010)	15.989.929
Population density (inhab/Km2)(2010)	365,23
Number of municipalities	92
Annual growth population rate (%)(2010)	11.13
GDP (USD) (2017)	308 Billons
Representation in national GDP (%)(2010)	10,8
Main exported products (2016)	Petroleum, fuel, siderurgy
Unemployment Rate (%)(2012)	6,4
Annual precipitation average	1250 mm

Sources: IBGE 2010 and Subsecretaria de Desenvolvimento Econômico RJ, 2018

The Northwestern region, also called Fluminense Northwest is one of the five regions in the Rio de Janeiro state. It comprises of 12 municipalities with a total area of 5.373 km^2 bordering Minas Gerais and Espírito Santo states. Its territory corresponds to 15,83% of the Rio de Janeiro state. The main hydrographic watersheds are the Itabapoana River, which separates the State of Espírito Santo, and the Paraíba do Sul watershed with its important tributaries: Rios Pomba, Muriaé and Carangola, cutting across the entire region.

From a demographic point of view, the region has a population density of approximately 53 inhabitants/km^2, and population corresponding to only 2.3% of the state with a concentration of 77% of its inhabitants in the urban areas. According to the 2010 census by IBGE, the Northwest region has a population of 317.493 inhabitants, with a density of 61 inhabitants/km^2. Unfortunately, the Northwestern Rio de Janeiro state shows the worst indicators with regards to the socioeconomic conditions, with a progressive economic depletion and high emigration rate. The GDP per capita is 8.850,15 USD, constituting the highest index of poverty in the state.

As mentioned earlier in this chapter, the Northwestern Region concentrates its economic and social development on agricultural production, mainly coffee and vegetables, livestock and milk production.

Itaocara together with Itaperuna, Porciúncula, and San Antonio de Padua, are the most important municipalities in the Northwestern Region, given their participation in the regional economy, the concentration of government institutions, size and population.

The municipality of Itaocara is located in the south part of Northwestern Region of Rio de Janeiro state. It covers about 431.335 km^2, and according to IBGE data in 2016, its population was 22.899 inhabitants in 2010, with a population density of 53,09 inhabitants/km^2.

Two rivers border Itaocara; the Rio Paraíba do Sul to the north and the Rio Negro that forms the southern border. The Itaocara municipality is part of The Mata Atlantica biome with a tropical climate and sits on an altitude of approximately 60 m.

The Itaocara municipality is divided into five districts; Itaocara city, Laranjais, Estrada Nova, Jaguarembé, and Portela. Conversely, the municipality is also divided into ten micro-watersheds Valão do Papagaio, Riberão das Areias, Córrego da conceicão, Valão do Barro Preto, Valão dos Castros, Córrego da Serra Vermelha, Valão do San Antonio, Valão da onça,Valão do Pati and Córrego do São Luiz e Jareraca.

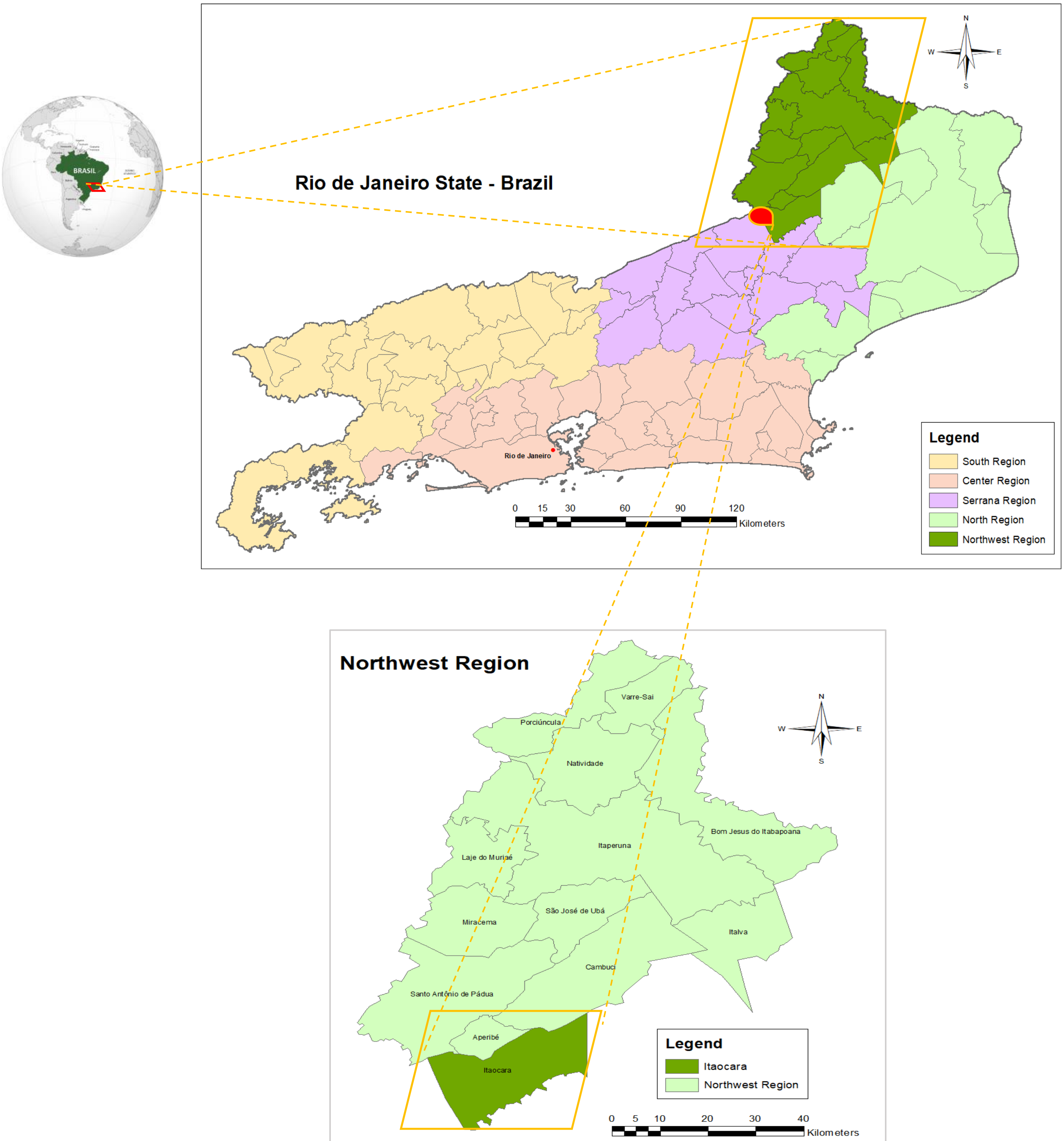
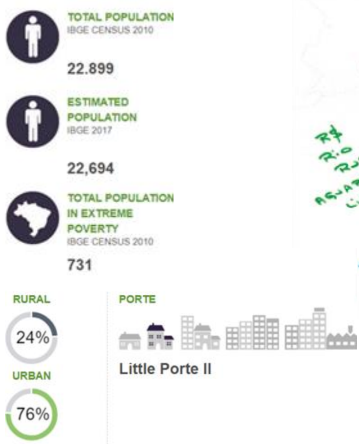


Figure 16: Study area Localization

Source: Own elaboration based on IBGE 2010, CIDE, Secretaria de Estado do Ambiente RJ 2015

Itaocara Municipality



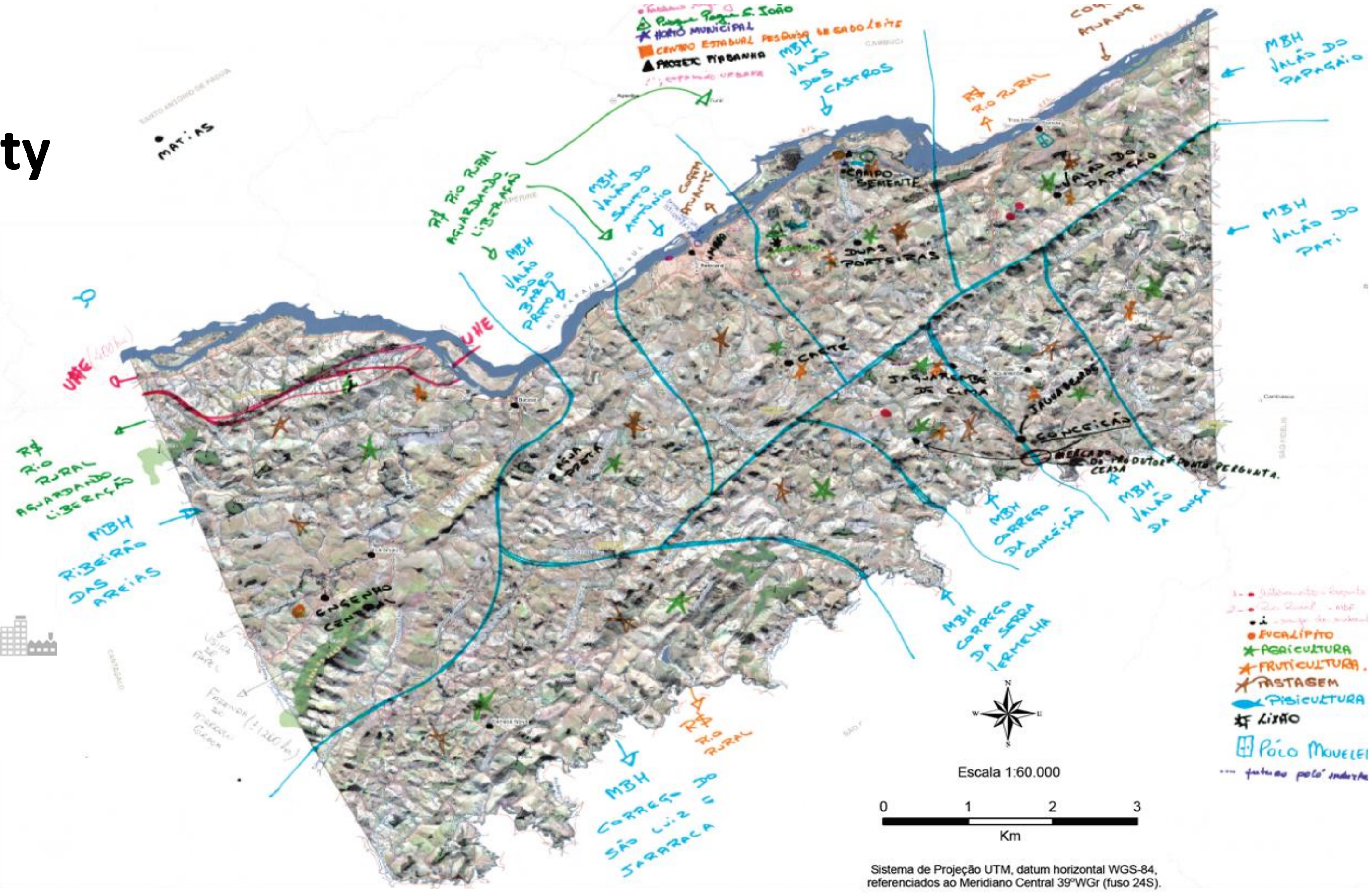


Figure 17: Map of Itaocara Municipality

Source: Secretaria de Estado do Ambiente RJ, 2015. Mapa falado. EMATER, MDS 2017

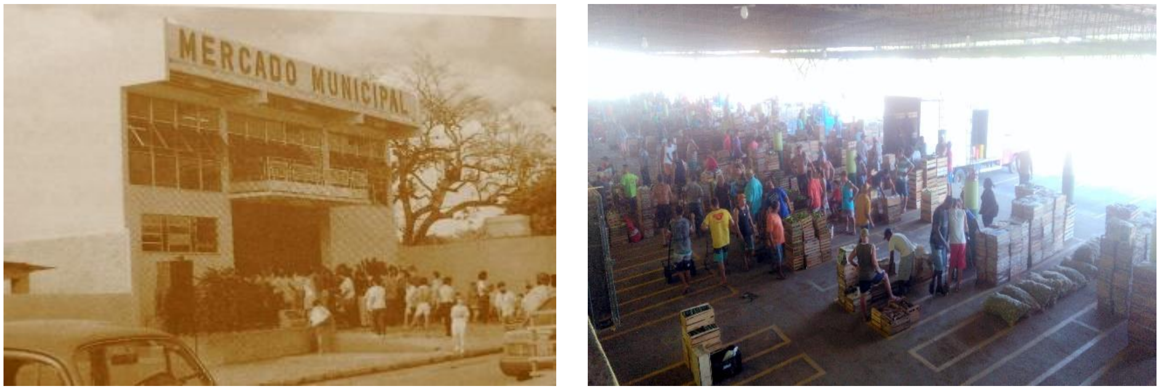
3.3 Historical, Cultural and Social Dimension

Itaocara was founded in 1809 by Frai Tomas de Castelo after the Portuguese colonization. Its name conserves its origins in the indigenous town of Puri, where "Ita" means: Piedra (stone) and "Okara" means Plaza (Place), in reference to mountain located on the opposite side of the Paraiba do Sul river.

Until the second half of the 18th century, the Northwestern region was occupied by the Puri, Coroado and Coropó indigenous peoples. From 1673 to 1850, the entire north of the state of Rio de Janeiro was considered under the municipality of Campos de Goytacazes, but in the mid-nineteenth century, the current territorial divisions gradually emerged. The year 1850 was characterised by the emancipation of the municipality of San Fidelis, to which Itaocara belonged and not until the end of the 19th century, before Itaocara would be recognized as an independent municipality.

During the 19th and early 20th century, economic activities focused on the production of coffee and sugar cane. However, after the emancipation of Itaocara, economic activity focused more on agricultural production. The production of coffee had a great peak, but in 1930, it was affected by the world economic crisis which caused the emergence of other economic activities, mainly livestock and dairy production; a situation still reflected in current days. Along with Itaocara, the municipalities of Varre-Sai, Porciúncula and Aperibé also focus their economic activities on agriculture.

Agriculture Association Itaocara 1927 / Dairy Association 2018



Municipality Market 1927 / 2018

Panoramic View of Itaocara 1927 / 2018

Image 1: Itaocara photo gallery 1927/2018
Source: Year 1927: www.itaocararj.com.br/historia-de-itaocara. Year 2018: Own Photography

By the beginning of this century, agricultural activity was under structures and conditions of the last century, added to the inadequate management of land, mainly because it was exclusively used for extensive livestock farming, avoiding the diversification of other economic and industrial activities and causing important displacements of the rural population to the cities. *(Figure 18)*

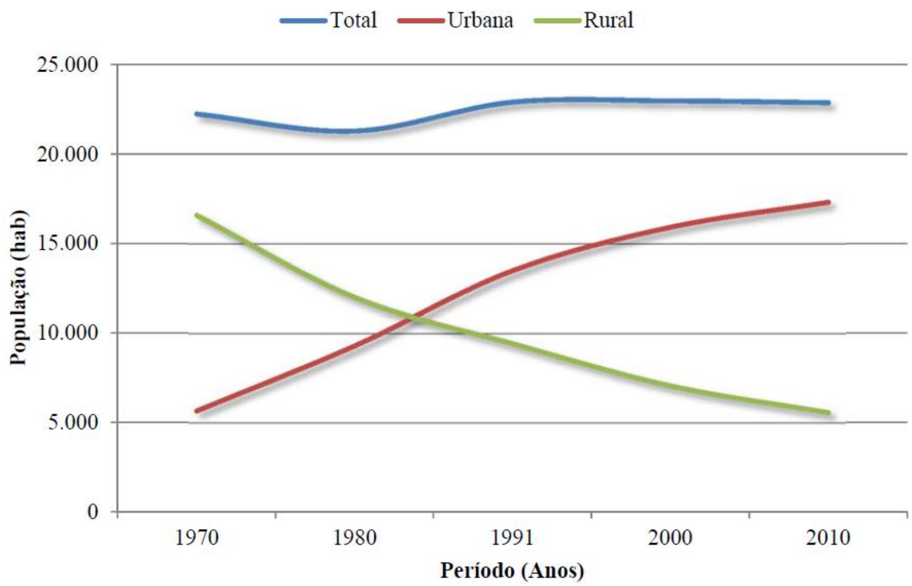


Figure 18: Displacements of rural population to cities – Itaocara 1970-2010
Source: (Prefeitura Municipal Itaocara, 2012)

Currently, fruit production and a variety of vegetables are gradually emerging mainly the Quiabo, while the economic activity is still rooted in livestock and dairy production mostly carried out by small producers and family farms.

The producers of Itaocara in recent days face challenges in adapting to new development cycles of the region and the country. It is difficult trying to focus their processes on sustainable activities supported by investments and autonomy in the production processes that involve environmental conservation, production economic and social justice.

According to the last population census in 2010 by the IBGE, in social terms, Itaocara presents the conditions as shown in *Table 8* below.}

Table 8: Itaocara social index

Itaocara Social Indicators – IBGE 2010	
Urban Population	17326
Rural Population	5573
Growth annual population rate	0,13%
Growth annual urban population rate	9%
Literacy Rate 6-14 years old	99.6%

Source: IBGE 2010

3.4 Economic and Political Dimension

Cattle farming and dairy production are the main economic sources for Itaocara. It is characterized by products based in the dairy processing industry which are intended to supply the regional markets. *(Figure 19)*

However, according to IBGE, the agricultural sector represents 17% of the GNP for the municipality *(Figure 20)*, 16% from the industrial sector and the services sector (excluding administrative services, public health, education and social security) constitutes 67%. This owes to the fact that majority of the inhabitants of Itaocara are concentrated in the city due to higher income from the service sector. In higher proportion are the textile and furniture manufacturing industry while in lesser proportion are the restaurants and handicrafts. Nevertheless, as earlier mentioned, the primary economic activity in the rural sector is the livestock for dairy production, placing the municipality among the largest milk producers in the state, with the leadership of the Cooperativa de Leite de Itaocara - CAPIL (Dairy Association of Itaocara).

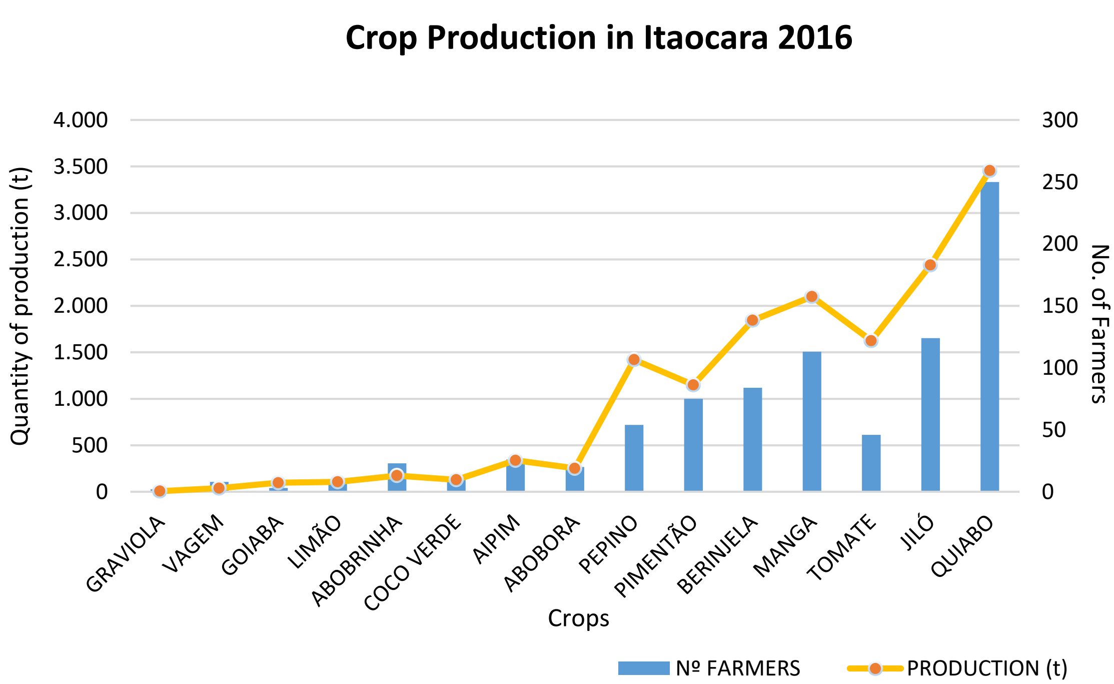


Figure 19: Crop Production Itaocara 2016
Source: Own elaboration based on EMATER 2016 Database

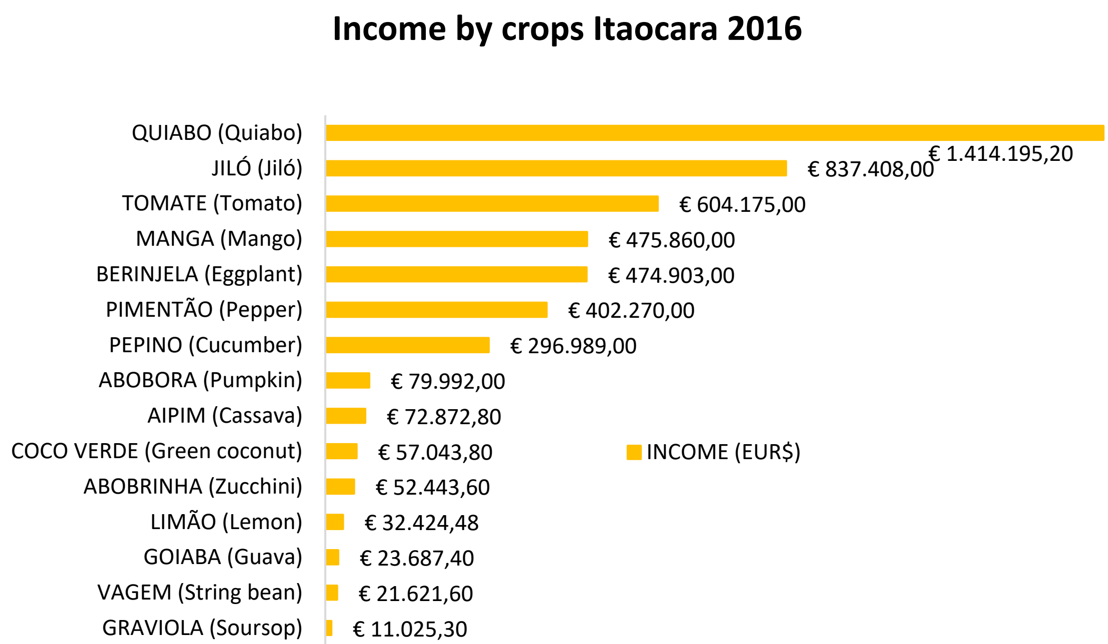


Figure 20:Income by Crop Production Itaocara 2016
Source: Own elaboration based on EMATER 2016 Database

Agricultural production in Itaocara also consists of raising livestock such as pigs and chickens, besides the breeding of horses, Tilapia fish, goats and sheep. It also includes the production of honey and eggs, which represents an important income source for the Itaocara economy. *(Table 9)*

Table 9: Income by Livestock Production Itaocara 2017

Livestock Production	No. Of Farmers	Annual Income (BRL)	Annual Income (EUR)
Honey	57	529.200	116.424,00
Eggs	174	602.910	132.640,20
Beef Meat	93	6.539.000	1.438.580,00
Sheep Milk	3	25.920	5.702,40
Fish Meat	15	175.200	38.544,00
Dairy Products	778	12.067.923	2.654.943,06

Source: EMATER 2017

Dairy production in Rio de Janeiro state is about half a billion litres of milk per year, which is about R $ 600 million, only from prices paid to farmers. In consideration with a domestic demand of 2.5 billion litres per year, this activity presents great potential for expansion (EMATER-RIO, 2017)

The GDP per-capita in Itaocara for 2015 was BRL 47.145,59 (EUR 10.478,45). The nominal average monthly per capita income in Itaocara varies between rural and urban areas, where the lowest percentage is for rural areas. The proportion of employed persons in relation to the total population was reported at about 18.6%

The political situation in Itaocara just like the general political situation in Brazil has undergone several changes. The executive power in the municipality is led by an elected mayor Dr. Manoel Queiroz Faria for period 2017-2020 who has been a mayor for two electoral periods 2001 to 1008. In December 2016, the mayor and agriculture secretary were condemned for economic and political abuse of power (Newspaper Extra, 2016).

Brazil generally joins the list of Latin American countries with the highest rates of corruption. Unfortunately, this situation is fundamental to the development of any public policy and it represents a social challenge facing the Latin American communities in general.

3.5 Environmental Dimension

Until the second half of the 18th century, the municipality of Itaocara was completely covered by the Mata Atlântica biome, which has been gradually devastated by clearing and coffee growing and later by the raising of cattle. Currently, 95% of the Atlantic Forest has been devastated, conserving only a few points of secondary vegetation. The land use for crops and pastureland is the most predominant use of soil in Itaocara and the Northwestern region (Secretaria de Estado do Ambiente RJ, 2015) According to the study of land use of Itaocara in 2001, it was reported that 84% of the soil corresponds to pastures. This percentage corresponds to 345068 km^2.

Regarding environmental dimension, Itaocara suffers from two specific problems of progressive change in climate and soil erosion. Itaocara has a tropical climate catalogued as (Aw): Wet-subwet dry. It presents heavy rains from November to February, which causes landslides in poorly covered soils, aggravating erosion problems. The soil type in the municipality is classified as Acrissols, where according to EMBRAPA - Empresa Brasileria de Pesquisa Agropecuaria (Brazilian Agricultural Research Company) which is considered not suitable for low-input ranching and cultivation systems. Therefore, agroforestry and shifting cultivation systems are now highly promoted (EMBRAPA, 2014).

Itaocara presents a Medium vulnerability degree to floods, landslides and overflows. As earlier stated, Itaocara focuses its activities on grazing land, livestock and agriculture, creating a strong pressure over the soil with loss of fertility and intensifying the erosive processes. Besides that, the geo-environmental characteristics of mountainous relief, soils with variable texture and intense rainfall regime makes Itaocara prone to degradation of biodiversity, water and soil.

From January and February 2014, until around October 2017, the state of Rio de Janeiro was severely affected by a dry season. In the Northwestern region, the soil moisture was highly reduced, affecting the crops and the pasture for animal feeding. As narrated by a farmer in the rural area of Itaocara "*People were not prepared for this type of drought, many farmers lost their animals because they did not have what to feed them (...) it has been a very difficult time*". Only 9.6% of producers have irrigation systems generally on very small areas (Emater-Rio & Pesagro-Rio, 2015).

Itaocara belongs to the Paraiba do Soul River watershed, where it supplies its demand for water resources, through direct capture for daily living, agriculture and livestock. The potable water supply is the responsibility of CEASA - Comanhia Estadual de Aguas e Esgotos (Water management company); a public company responsible for supplying water for Itaocara, Aperibé, Cambucci and Tres Irmaos. It serves more than 18,000 users in urban areas and distributes 9,169 m^3 of treated water daily (Data of 2010) at a per capita consumption of 213,80 L (Hab-day). The water supply in rural areas is mostly provided by underground wells illegally installed by the population. Unfortunately, the INEA - Instituto Ambiental del Estado (State Environmental Institute), cannot account for the underground wells within its databases (CEASA, 2018) (*Personal interview with CEASA Itaocara director*).

When the collection of groundwater exceeds the limits of natural aquifer recharge, the population is forced to deepen their wells brings with it greater energy consumption for pumping, causes soil degradation and once again triggers erosion, loss of water and diversity.

In spite guidelines established in Lei 11.445 - Diretrizes Nacionais do Saneamento Básico (National guideline for basic sanitation), Itaocara does not have a treatment system for domestic wastewater and sewage, which are disposed of directly into freshwater sources or in septic wells. Within Itaocara urban centre, the wastewater is disposed of in the River Paraiba do Sul through a collection of mixed network of rainwater and domestic wastewater. This situation presents a great challenge for the authorities and the population in Itaocara, given that in addition to environmental pollution over the Paraiba do Sul river basin, it also presents serious risks for public health (Prefeitura Municipal Itaocara, 2012).

This is aggravated by the use of fertilisers and agrochemicals for the irrigation of crops in rural areas, which discharges directly into water bodies, constituting a serious threat to the environment and public health (EMBRAPA, 2014).

3.6 Legal Framework Regarding Food Security

Concerning Food and Nutrition Security - Segurança Alimentar e Nutricional-SAN, Brazil became an example and a world reference in its fight against hunger, under the banner of the program Zero Hunger or Fome Zero established in 2001. The Fome Zero program became the main government strategy for the orientation of social and economic policies in the country. This program allowed the elaboration of structural policies in the fight against hunger, strengthening family farming supported by legislation and a national policy of food and nutritional security. This program was the result of multiple efforts of civil and political organisations for more than two decades.

The National Food and Nutrition Security Policy in Brazil is supported by the Organic Law of Food and Nutritional Security – LOSAN. It is the Law No.11.346 which establishes the Food and Nutrition Security System – SISAN (Comunidad de los estados Latinoamericanos y Caribeños - CELAC, 2018).

This Law published in 2006 aims to establish the definitions, principles, guidelines, objectives and composition of the SISAN, by which the public power, with the participation of civil society, formulates and implements plans and agreements to ensure the human and social right to adequate food. (law 11346/2006). The Interministerial Chamber of the SAN, the National Council of the SAN and the National Conference of SAN, are institutions linked to the fulfilment of this law.

Some laws associated with this main law are:

- The constitutional entrustment No.64 / 2010 to the political constitution of 1988 which incorporates an explicit and direct recognition of the right to food in its article 6 as a social right.
- Law 11.947 for school feeding
- Law 11.326 National policy on family agriculture and rural family enterprises.
- Law 11,284 Law of public forests

It is also necessary to highlight the food security programs that are currently being developed.

Food Purchase Program - PAA: It is a program of food supply, food aid and public purchases for the benefit of family farmers, indigenous and traditional communities or rural family businesses and also people in situations of food and nutrition insecurity (CONAB, 2016). This program uses marketing mechanisms that favour the direct acquisition of products from family farmers or their organisations, stimulating the processes that add value to their production. This program is derived in five modalities:

1. Support to family farming for the formation of stocks and its commercialisation.
2. Direct purchase from the family farmer when there is a decrease in the offer or the sale price.
3. Incentive to the production and consumption of milk through its free distribution, particularly directed to the north-eastern states.

4. Purchase of products for family farming for donation to people in situation of food and nutritional insecurity.
5. Institutional purchase for the regular demand in the consumption of food by the states, the federal district and the municipalities.

National program to strengthen family farming - PNFAF: It is a program of financing individual or collective projects that generate income for family farmers. This program is implemented by different financial entities to support the costs of harvesting or agricultural activities, purchase of machinery, equipment or infrastructure for the production of agricultural services. Likewise, the food acquisition program presents different lines of credit, with the lowest interest rates in rural financing.

National Program of School Feeding - PNAE: Implemented in 1955, this program seeks to benefit more than 42 million students in basic education (children, primary and middle school youth and adults) enrolled in public schools, philanthropic and community entities. Its main objective is to contribute to the growth, development, learning and school performance of students and the formation of healthy eating habits by the school feeding supply with access to food and nutrition education.

In this program, the delivery of school meals to students is made through transfers of financial resources by the National Fund for the Development of Education - FNDE to the states, federal district and municipalities.

A very important aspect within this program is the as stated in Law 11.947/2009, which establishes that "a minimum of 30% of the value transferred to the states, municipalities and Federal District by the FNDE for the National Programm of School Feeding (PNAE), must be used in the purchase of food from family farming and the rural family entrepreneur or their organizations giving priority to agrarian reform settlements and traditional or indigenous communities".

Bolsa Familia Program: It started in 2003 as a program of monetary transfers that help to combat poverty and inequality in Brazil, this program seeks to benefit all families in poverty and extreme poverty. The types and amounts of benefits in cash transfers to a family depends on the composition of the family (generally it is greater if families have children or adolescents) and their monthly income-per-capita is less than USD57.

National Financing Program: It was implemented in 2008, and includes projects associated with all crops and agricultural activities of family farmers. Primary responsibility for their development are the National Bank of economic development, Banco do Brazil and financial institutions.

3.7 Food Access, Quality and Quantity

According to the Ministry of Health of Brazil (Health Ministry of Brazil), Brazil is a country that is self-sufficient in the basic production of foods consumed by the population (except wheat) (Ministério da Saúde, 2016).

Regarding with FAO Report in 2014 Brazil showed that the malnutrition indicator was below 5%, where the rate of childhood chronic malnutrition was substantially reduced from 7.1% in 1989 to 1.8% in 2006 thanks to the policies developed during the implementation of the National Program Fome Zero. It is a global reference policy in Food Security and the construction of the National Policy on Food Security in Brazil, both based on the continuing struggle against poverty. Increasing population income and employment and also with the implementation of programs that have contributed to food security in Brazil, such as the PNAE (School Feeding Program) or the PRONAF (National Family Farming Program). It also seek to reduce obesity rates , malnutrition, consumption of sugars, salts, gluten and increased the consumption of vegetables, fruits and drinking water (Ministério do Desenvolvimento Social e Agrário do Brasil, 2017) .

As was mentioned above, food security has three main aspects: Food access, quality, and quantity.

Regarding the first aspect, Food Access, it is directly affected by indicators includes the extreme poverty and poverty. The first one in Brazil was 7.6% in 2004 and 2.8% in 2014 and the poverty indicator was from 22.3% to 7.3% in the same period of time (IBGE, 2010).

Other aspect that limit the Food access is the concentration of land, given that 24% (80,1 million ha) of the area available for agriculture belongs to family farming and 75.9% belongs to agricultural production for "Non - familiar farmers". It usually means monocultures generally for export (Ministério do Desenvolvimento Social e Agrário do Brasil, 2017). That situation promotes inequality in the access to food and shows that despite being a country with a diversity in food production, with sufficiency and autonomy it still presents an important challenge to guarantee access to food for all its population.

The Food Quantity can be measured in Kilocalories, for the case of Rio de Janeiro, it was 2400 Kcal-capita / day in 2009 (IBGE, 2010) taking into account that the minimum value established by the FAO is 1800 Kcal -capita/day. The last report showed that Brazil exceeds this amount by 131% (FAO, 2016).

The Food Quality has been strongly studied in the last times, this is generally due to the obesity trend that the population is presenting, which in 2016 reported that 18.9% of Brazilians are obese, in Rio de Janeiro this figure is even more alarming -55.8% (Ministério da Saúde, 2016), understanding that obesity is measured as (Weight / height2) (Figueroa Pedraza, 2003), for the case of estimating obesity means that this value should be > 30 kg/m^2, affecting mostly the male population. On the other hand, the malnutrition or chronic energy deficiency is defined when the measure is < 18kg/m^2, the last official report from Brazil shows that in 2009, 5.1 million people had a malnutrition index (IBGE, 2010) and in 1995 a 4 % of malnutrition was in urban population and 7.5% in rural population (Figueroa Pedraza, 2003).

For Food Quality is necessary to refer to four important problems. The first is the use of agricultural toxins, which are used to fight weeds or fungi and the use of chemical fertilizers which are used to potentiate the crop productivity, both with negative consequences over health of population and over the environment. it is often linked with the access to water for irrigation that is combined with these chemicals and then it is infiltrated into the soil again or even the access to water for washing and preparation of foods.

Another important aspect is the incursion of genetically modified foods in the Brazilian market. Despite presenting informative tables*, it does not have clearer information for the consumer about the possible negative consequences over their health when they buy genetically modified or transgenic foods*. As was expressed by Fernanda Manciera biologist and housewife of Itaocara. The third aspect is the diseases related to malnutrition such as diabetes, heart disease, and hypertension. It is estimated that deaths from diarrhea in children < 1 year and older people are generally due to the consumption of contaminated food (IBGE, 2013), in addition to the intake of unbalanced diets or contaminated food, generally due to sanitary and hygiene deficiencies in handling, mostly in marginalized or low-income sectors.

The last aspect is regarding with the consumption habits and lifestyles, where a study conducted by the Ministry of Health of Brazil (Ministério da Saúde, 2016), shows how the population, in general, has changed their traditional diets or dinners for fast meals in the so-called "Lanchonetes", which becomes habitual and often necessary due to factors linked to time and purchasing power.

4 Results: Evaluation of Food Flows


Landscape in Itaocara. Own Photography. 2018

"The food comes into conflict with itself because it has been torn violently from the tissue of which it is a part - local economies - and it is launched first to the market and then for disposal, as a waste. This way of proceeding results in the ecological degradation, hunger and poverty. The future of food depends on remembering that the tissue of life is made up by Food. "

Vandana Shiva

This chapter presents the food flows identified during the field work in the Northwestern region of the state of Rio de Janeiro, specifically in Itaocara. As mentioned in the introductory chapter, for identification of food flows different interviews were conducted, with review of reports from public and private entities and direct observation which provided insights into the flow of food through its process of production, transportation, marketing, consumption and disposal.

Taking into account the wide diversity of food that is produced in the Northwestern region, for the development of this work only two were chosen as most relevant flows for economic and social development in the region and with the greatest environmental impact. These are Dairy Flow and Horticulture Flow.

Dairy flow refers only to raw milk, and during its process of transformation and commercialisation, other derived products such as processed milk, cheese and butter are highlighted. However, the main flow is focused on raw milk. In understanding the Horticulture flow, it is necessary to describe what is understood here by the term horticulture. It is a term that includes the production of highly diversified and useful plants for human well-being. Similar to horticulture, there is production of crops in large size as the production of grains and fibres as well as the forestry production which includes the production of floral species, or fodder production. Nevertheless, this study only takes into account the horticulture.

The horticulture comprises the production of vegetables, fruits, flowers, medicinal plants among others. However, for this study only the production of fruits and vegetables is investigated according to the availability of information and relevance of its production in Itaocara.

4.1 Stakeholders Identification

Given the diversity of stakeholders that are involved in food flows, plans and policies regarding food security present great challenges. The stakeholders that influence the dairy and horticulture flows have different roles, capacities, needs and interests with very important relationships between them.

The primary stakeholders are the associations, groups of people or institutions that are directly related to the processes of production, transport, distribution, marketing, consumption and discarding of food, within which is possible to identify:

- **Family Farmers of fruits and vegetables:** They are those whose only activity is the production of fruits and vegetables, generally in small areas of their own property or in a rented property. This also include workers who are employed by other family farmers generally in the harvesting season. Generally, the fruits and vegetables are transported directly by the producer to the point of market of Itaocara, but sometimes those are also sold directly to wholesale markets in the city of Rio de Janeiro.
  Among these category of producers in Itaocara is necessary to highlight the producers of Guava and Quiabo. The 70% of Guava production is destined to handicraft production of sweets, it is around to 225 kg/day which is transported to the municipality of Sao Fidelís in the North Region of the state and also to the city of Rio de Janeiro; then the Guava sweets are marketed throughout the region by wholesale and retail consumers in municipalities such as Itaperuna, San Antonio de Padua and Bom Jesus. The other 30% of Guava Sweet is commercialized in Itaocara.

Image 2: Guava Sweet production
Source: Own Photography 2018

- **Family farmers of dairy products:** These are producers who dedicate their economic activity to the raising of dairy cattle and production of raw milk usually on their own land. There are usually family groups where the whole family participates in the care of the cattle and the milking activities every single day. On average, these producers have 20-30 dairy cows, with a production of raw milk around 10,000 litres/month. These producers usually have tanks for preservation and cooling of the milk before the collection.

- **Mixed Family Farmers:** This comprise of family farmers in Itaocara who have dedicated their whole lives to farming work and combine their activities between fruits and vegetable crops and milk production on a small scale. They produce approximately 3,000 litres of raw milk/month and 200 kg of fruits and vegetables per week.

- **Dairy Association - CAPIL:** Founded in 1950, it is one of the most important cooperatives in the Northwestern region with more than 1,600 associates. It has 49 direct employees who are responsible for milk collection at the production points, carrying out nine daily collection routes in Itaocara and neighbouring municipalities and also responsible for the production of pasteurised milk, cheese and butter. CAPIL collects approximately 70,000 liters of milk/day (2.100.000 litres/month). The vast majority of collected milk is sent to the municipality of Barra Mansa in the Southern region of Rio de Janeiro state for production of long-life milk and the what is left is marketed directly with Nestle © which is a private company located in the municipality of Tres Rios also in the Southern of the state.

Image 3: Dairy Association Itaocara – CAPIL
Source: Own Photography, 2018

- Other Dairy Associations: Some of the dairy producers, prefer to be part of other associations in other municipalities, and sell their products without any restriction by CAPIL. Others prefer to sell directly in Barra Mansa, depending on the variation in selling prices.

- NESTLE©: It is a company recognised worldwide for the production of more than 1,000 items derived from the dairy industry. It has a factory in the municipality of Tres Rios in Southern region, where some of the raw milk produced in Itaocara is delivered. This factory distributes around 124,000 tons of products per year within the interior of the state including the states of Mina Gerais, Sao Paulo and Espiritu Santo.

- CEASA ITAOCARA: CEASA are the Food Supply Centers. The CEASA in Itaocara was inaugurated as Mercado do Produtor de Ponto de Pregunta - CEASA Northwest in 1982. In this public space regional products such as fruits and vegetables are mostly marketed.

However, they also market the production of neighbouring municipalities such as Sao Sebastian do Alto, Sao Fidelís, Cambucci, Aperibé, Pádua, Miracema, Italva, Nova Friburgo, among others exclusively belonging to the state of Rio de Janeiro. It is restricted only to Rio de Janiero state and the marketing of products that come from other states is not allowed. The CEASA - Itaocara products are mainly delivered to CEASA Sao Gonzalo in the Serrana region and Ceasa Rio de Janeiro in the capital city, where the products are transported through wholesalers.

- Food Bank of Itaocara: It was inaugurated in 2014 with the purpose of avoiding and minimising the waste generated in CEASA. It is currently part of the Food Purchase Program (PAA) with the purpose of favouring both the family farmer and philanthropic institutions such as nursing homes, hospitals and NGOs. The food bank buys directly from the producers the remnants of their production or sometimes important percentages of their production in order to supply food toward the philanthropic institutions in Itaocara, San Fidelis, Campos dos Goytacazes and Cantagalo. In 2017, the Food Bank of Itaocara managed 135 tons of fruits and vegetables from 105 small family farmers in 26 philanthropic institutions in the region.

- Associations of other products: Itaocara produces the best honey in the state of Rio de Janeiro according to Mr. *Edilbar Carrero*, president of the Honey Association. In Itaocara, 19.600 litres of honey are produced per year from December to February. During these months, Honey production is an alternative activity to the production of fruits and vegetables.

- National Program of School Feeding - PNAE: It is based on the National Food Acquisition Program headed by the Ministries of Education and Social Development of Brazil, which provides the school meals through the National School Feeding Program - PNAE. It is considered of special importance because it supports the family farmers and schools. It also encourages the healthy consumption of food locally produced, given that this program includes menus and diets professionally designed.

  This program works through an Annual Public Tender, where it expresses the food requirements in the different regions and municipalities of the state and the quantities and conditions. Interested farmers then must make a registration in order to supply these products. In Itaocara, the purchase to farmers is made by the City Hall with support of the Secretary of Education. In 2016 the PNAE transferred to Itaocara EUR 46.765,0 from the National Fund for the Development of Education out of which EUR 8,864.8 were acquisitions from Family Farming (18.9%), serving 55 schools (1913 students). However, the PNAE considers that this percentage must be 30% and there is not any sanction for municipalities that do not fulfil this requirement.

  According to public tender No. 002/2018, the food requirement for the PNAE program in Itaocara includes around 14,250 kg of fruits and vegetables weekly.

The secondary stakeholders are generally institutions that are indirectly part of the food flow but are considered fundamental for their development. These are:

- Banco do Brazil: According to the interview with the manager in Itaocara office, it was possible to identify the Bank as an important stakeholder, especially for its participation in the PRONAFI Program, which seeks to support the family farmer through loans. As *Dr. Jose Arlindo* affirms, the loan portfolio in Itaocara is very solid, meaning the credit to the rural farmer or family farmers presents high credibility, for which it is viable to support projects such as purchase animals, fertilisers and increase their productive capacity. However, many bureaucratic procedures exist, limiting the access to these funds, where the farmer must invest enough time and money in order to obtain letters, permits, recommendations and technical reports.

- EMATER: This is a company responsible for technical assistance and rural extension in the State of Rio de Janeiro, with a central office in the city of Rio de Janeiro, five regional offices and 72 local offices. It is a fundamental part for the development of food flows in the region. Particularly, the Itaocara office stands out for the trust and support given to family farming by technicians who have dedicated more than 40 years to this work searching out for fair and sustainable development.

Image 4: EMATER Workshop in Itaocara
Source: Mateo Aguilar,1980

- Municipal Hall Office and Secretary of Agriculture: These entities are representing the executive power and are a fundamental part for the decision making and execution of the national plans and programs in Food Security.

4.2 Flow of Dairy and Horticulture Products

According to the different processes that are carried out during the Horticulture and Dairy Flows within the metabolic processes and the role played by the stakeholders, the following model is presented, where the interrelations that lead the food flow in Itaocara are identified. In addition, each of the processes involved in the flows is detailed qualitatively and quantitatively as well.

The dairy and horticulture flows refer particularly to raw milk flow and its main derivatives such as cheese and butter, while horticulture flows refer to 15 main crops including vegetables and fruits.

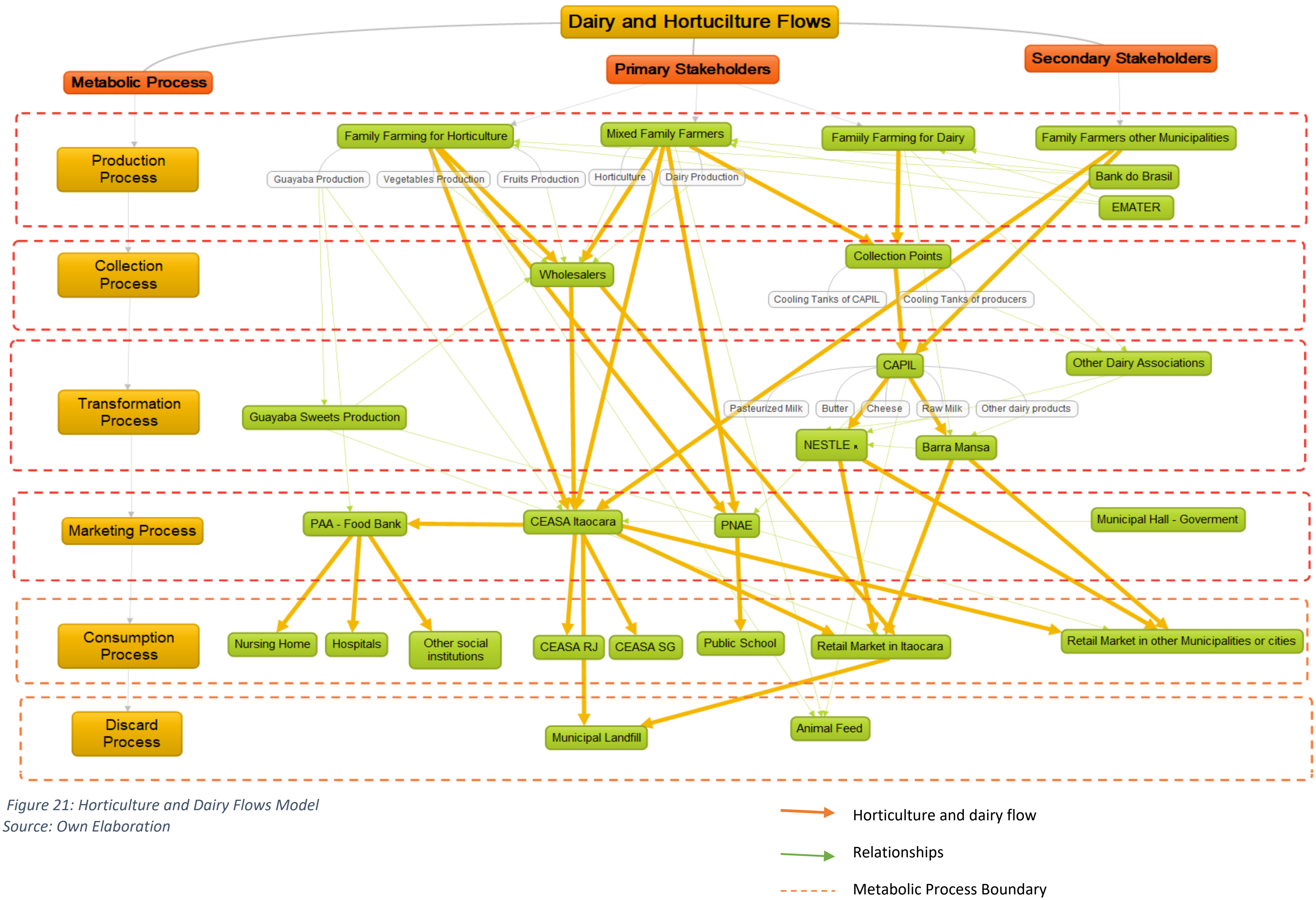


Figure 21: Horticulture and Dairy Flows Model
Source: Own Elaboration

4.2.1 **Production Process**

The production of food in Itaocara is carried out 100% by family farmers. Family farming is an agricultural activity developed basically by rural families for self-consumption and sale as the main economic activity.

According to the last agrarian census developed by the IBGE in 2006, Itaocara has 1612 units related to family farming, where 1357 are owners, 53% of which developed their activities in areas between 1-10 ha, 10% in an area of 10-20 ha, 21% in areas between 20-50 ha and 6% from 50 to 200 ha.

As mentioned earlier in chapter III, Itaocara is a municipality that focuses its production on agricultural and livestock activities which are developed by small and medium producers. Therefore, family farming is the centre of the agricultural and economic development in the municipality being the main source of food supply for the region and state.

Several factors influence the family production. This included access to land, water and energy resources, fertilisers, information, financial support, education among others that make family farming the centre of policies and programs aimed at guaranteeing food security in a community.

For the purposes of this work, family farming has been classified into three categories of (1) Farmers who are dedicated exclusively to the production of fruits and vegetables, (2) Families that are engaged in the dairy production, and (3) Families that they mix these two activities. However, the results presented are shown only in general quantities within the horticulture and the dairy flows.

Regarding the Horticulture Flow, it is necessary to specify that the crops correspond to the main crops in Itaocara without ignoring the fact that the municipality has an immense variety of crops. This is however not representative of quantities for which the crops detailed here correspond to.

Table 10:Crop Production in Itaocara 2017

Portuguese Name	English Name	Illustration	Total Production Northwestern Region (t)	Year 2017		
				No. Of Farmers Itaocara	Quantity Production Itaocara (t)	Area (ha) Itaocara
Abobora	Pumpkin		1122,6	12,0	60,0	4,8
Abobrinha	Zucchini		152,2	22,0	87,3	7,8
Aipim	Cassava		1001,4	12,0	80,5	6,0
Berinjela	Eggplant		1497	66,0	973,0	48,0
Coco verde	Green coconut		1019,7	10,0	169,8	9,5
Goiaba	Guava		434	3,0	20,0	1,5
Graviola	Soursop		5,5	2,0	3,0	1,5
Jiló	Scarlet Eggplant		4984,2	84,0	1547,0	64,0
Limao	Lemon		853,8	5,0	48,0	3,0

Manga	Mango		1700	92,0	1700,0	85,0
Pepino	Cucumber		8378,5	33,0	603,5	17,0
Pimentao	Pepper		5062,5	57,0	874,5	36,0
Quiabo	Okra		4565,4	147,0	2392,0	180,0
Tomate	Tomato		48370,4	22,0	795,0	13,5
Vagem	String bean		51	7,0	51,0	3,0
Total			**79198,6**	**574,0**	**9404,6**	**480,6**

Source: Own Elaboration based on EMATER 2017 Database

Horticultural products from Itaocara represent 12% of the total production in the Northwestern region.

Here, Quiabo is the most representative product with 25% of the total, followed by Manga (18%), scarlet eggplant (16%), Eggplant (10%) and Tomato (8%).

The production of fruits and especially vegetables like the Quiabo begins with its sowing in March and April and cultivation until the end of September and October. Later, the most important commercialisation with the best prices according to CEASA is given during the months from December to February.

In Itaocara, the acquisition of seeds is done directly by the agricultural input companies under the recommendation of technicians for rural consultancy or private engineers of these companies. Some farmers take their seeds to greenhouses for germination, then transplant to their own land.

The last 3 years has witnessed variable production of fruits and vegetables in Itaocara *(Table 11).* In 2015, Itaocara experienced increase in its production and number of land used for growing. This was also reflected in 2016, where the production was very high. However, for the year 2017, there was a fall in production which according to the producers was attributed to severe drought season. This was confirmed by Mr. Odilón, with the caption "*Never had lived a drought as violent as the last year*".

The drought condition also affected the production of raw milk. Mr. Gustavo Martínez also affirmed "*The cows got very thin, they did not have water to drink, and we had to mix the water with sugar cane just for us not to see the animals die, but that does not nourish them, it was only for them to survive (...) other farmers had saved some food for their animals.* "

Table 11: Crop Production 2015,2016,2017

Crop Production								
Year 2015			Year 2016			Year 2017		
No. Of Farmers	Quantity Production (t)	Area (ha)	No. Of Farmers	Quantity Production (t)	Area (ha)	No. Of Farmers	Quantity Production (t)	Area (ha)
681	10509,5	605,8	849	15140,8	751,35	574	9404,6	477,55

Source: Own Elaboration based on EMATER Database

Milk production in the Northwestern region is the second most important in the state after the Southern region *(Table 12).* In the Northwestern region, 127,414.716 litres of milk were produced in 2016, while in the Southern region, the production was 180,236.000 litres. In Itaocara, the milk production is carried out by 1273 producers according to the 2006 agricultural census. However, EMATER reported a dairy production of 12,067.923 litres with 778 producers in 2016 and 11,338.420 liters with 758 producers in 2017.

Table 12: Dairy Production in Northwest Region 2016

Dairy Production in Northwestern Region 2016				
Northwestern Region	Number of Farmers	%	Production Quantity (L)	%
Aperibé	266	6%	3.188.353	3%
Bom Jesus do Itabapoana	506	10%	17.119.371	13%
Cambuci	650	13%	13.962.000	11%
Italva	244	5%	8.673.147	7%
Itaocara	778	16%	12.067.923	9%
Itaperuna	602	12%	21.642.954	17%
Leje do Muriaé	177	4%	5.803.960	5%
Miracema	277	6%	5.902.914	5%
Natividade	251	5%	8.759.204	7%
Porciúncula	178	4%	5.869.345	5%
San José de Ubá	335	7%	5.166.007	4%
San Antonio de Padua	423	9%	14.314.320	11%

Varre-Sai	147	3%	4.945.218	4%
Total	4834	100%	127.414.716	100%

Source: Own Elaboration based on EMATER Database

Itaocara has 16% of dairy producers. However, they produce only 9% of raw milk in the Northwestern region, which shows the potential in the dairy production, especially, reviewing the efficiency of municipalities as Bom Jesus, Cambuci, Padua and Itaperuna. *Table 13* shows the dairy production in each watershed in Itaocara.

Table 13: Dairy Production in Itaocara 2016

Dairy Production in Itaocara 2016	
Micro-watershed	**Raw Milk Production (L)**
Córrego São Luiz e Jararaca	1.548.444
Córrego da Serra Vermelha	1.092.908
Córrego da Conceição	979.025
Valão do Pati	979.023
Valão Santo Antônio	1.092.908
Valão do Barro Preto	1.092.908
Valão da Onça	1.776.213
Valão do Papagaio	1.092.908
Ribeirão das Areias	1.434.560
Valão dos Castros	979.023
Total Production Itaocara	**12.067.923**

Source: Own Elaboration based on EMATER Database

Family farmers for dairy production are small farmers who developed their economic activities in areas < 4ha. (IBGE, 2006). With the assumption of 4 ha per each small dairy producer, it is possible to establish a total area of 3032 ha for dairy production.

4.2.2 **Transport Process**

Itaocara has important social and commercial relations with the neighbouring municipalities in the Northwest region such as Sao Antonio de Padúa, Miracema, and Cambucci, but also with municipalities such as Sao Fidelis in the Northern region or Cantagalo and San Sebastian do Alto in the Serrana region.

The dairy flow has its highest consumption in the municipality of Tres Rios and Barra Mansa in the Southern region of the Rio de Janeiro state, where dairy products then are distributed mainly in the city of Rio de Janeiro.

The milk cooperative CAPIL in Itaocara has installed 291 tanks for the collection of raw milk, these tanks are located with a distance of 3 km from each other, and some are owned by the same producers according to the raw milk produced, but most are points of collection of producers that are located within 3 km radius.

CAPIL Itaocara has 10 trucks to make a raw milk collection every 48 hours. In each collection point, the milk is received from the producers at a time from 6:00 am to 10:00 am by a worker of the cooperative who also is responsible for carrying out the first tests of milk quality. Later on from 11:00 am to 2:00 pm the collection is done through 8 routes distributed between the municipalities of Aperibé, Cambuci, Cantagalo, Miracema, Sao Antonio de Padúa, Sao Fidelis, San Jose de Ubá and Sao Sebastian do Alto.

Image 5: Delivery and Collection of raw milk by CAPIL
Source: Own photography

On the other hand, the horticulture products are delivered by farmers in Itaocara, Itaperuna, San Sebastian do Alto, Macuco, Sao Fidelis, Padua, Cambucci, Italva in the marketing point of CEASA in Itaocara through owned trucks or rented ones.

In CEASA Itaocara, the fruits and vegetables are bought by wholesalers who direct the foods to CEASA Rio de Janeiro and CEASA São Gonçalo in the Centre region. Some farmers also deliver their harvest directly to wholesalers who sell the products around the region and in the capital of the state.

To determine how much distance is travelled by food within its flow also called the "Food Miles" calculation, requires full knowledge of variables such as collection routes, frequencies, types of vehicles used, types of fuels and consumptions, distances travelled among others that allow the calculation of the carbon footprint, for the determination of CO_2 emissions.

The main distances travelled by the food produced in Itaocara to its main destinations areas shown in the table below.

Table 14:Main distances in dairy and horticulture flow

Main distances in Horticulture Flow			
Process	**From**	**To**	**Km**
Collection	Itaocara	CEASA Itaocara	13,6
	Itaperuna	CEASA Itaocara	98,8
	Sao Sebastian do Alto	CEASA Itaocara	26,2
	Macuco	CEASA Itaocara	47,4
	São Fidélis	CEASA Itaocara	38,3
	Santo Antônio de Pádua	CEASA Itaocara	35,4
	Cambuci	CEASA Itaocara	33,2
Distribution	CEASA Itaocara	CEASA Rio de Janeiro	253
	CEASA Itaocara	CEASA São Gonçalo	218
	Itaocara	CEASA Rio de Janeiro	266

Main distances in Dairy Flow			
Process	**From**	**To**	**Km**
Collection	Aperibe	CAPIL Itaocara	6,1
	Cambuci	CAPIL Itaocara	22,9
	Cantagalo	CAPIL Itaocara	54,5
	Miracema	CAPIL Itaocara	39,2
	Santo Antônio de Pádua	CAPIL Itaocara	23,6
	São Fidélis	CAPIL Itaocara	51,9
	Sao José de de Ubá	CAPIL Itaocara	58,2
	Sao Sebastian do Alto	CAPIL Itaocara	39,3
Distribution	CAPIL Itaocara	Barra Mansa	288
	CAPIL Itaocara	Nestle- Tres Rios	164
	Barra Mansa	Rio de Janeiro City	135
	Nestle- Tres Rios	Rio de Janeiro City	132

Source: Own elaboration

4.2.3 Marketing Process

The marketing of fruits and vegetables described in this work is given through three channels:

a) CEASA Itaocara

Horticultural products from the Northwest, North and Serrana regions come each week to CEASA Itaocara for it to be marketed. Nevertheless, this marketing point just receive 17% of the total production. The marketing process of fruits and vegetables by CEASA during 2017 is described in the following tables:

Table 15: Total Quantity Marketed by CEASA 2017

Production Place	Marketing by CEASA (t)	Quantity Production (t)	Proportion (%) Production/Marketing
Northwestern Region			
Italva	1527,0	5382,75	28%
Itaocara	12159,5	9404,55	129%
Laje de Muriae	23,0	44,3	52%
Aperibé	1485,0	2265,0	66%
Cambuci	1229,7	15408,0	8%
San Antonio de Padua	1813,7	2870,0	63%
Sao José de Ubá	1648,0	32053,0	5%
Miracema	614,9	2070,8	30%
Natividade	0,0	591,5	0%
Porciuncula	0,0	1672	0%
Itaperuna	3,4	5141,8	0%
Varre-Sai	2,5	24,0	10%
North Region			
Sao Fidelis	2981,8	3965,5	75%
San Fco. Itabapoana	36,4	44687,0	0,1%
Serrana Region			
Cantagalo	33,3	286,0	12%
Bom Jardim	31,5	26650,0	0,1%
San Sebastian do Alto	5197,1	18117,8	29%
Macuco	70,0	76,0	92%
TOTAL	**28.856,6**	**170.709,9**	**17%**

Source: Annual Inform CEASA,2017, EMATER Database 2017

Municipalities such as Natividade, Itaperuna and Porciúncula belongs to the Northwestern Region. However, those municipalities do not trade their production in CEASA Itaocara.

The 42% of the total horticultural products traded by CEASA are from Itaocara. The follow table discriminate this marketing process.

Table 16: Quantity Marketed by CEASA Itaocara 2017

ortuguese Name	English Name	Quantity Marketed (t) by CEASA - ITAOCARA CEASA			
		Total CEASA	From ITAOCARA (t)	Proportion (%) from ITAOCARA	From Other Municipalities (t)
Abobora	Pumpkin	99,7	49,6	49,70%	50,16
Abobrinha	Zucchini	163,2	81,8	50,13%	81,40
Aipim	Cassava	219,3	108,5	49,48%	110,81
Berinjela	Eggplant	2.504,1	1210,8	48,35%	1.293,39
Coco verde	Green coconut	89,9	64,5	71,74%	25,42
Goiaba	Guava	6,3	5,2	81,54%	1,17
Graviola	Soursop	23,2	18,7	80,50%	4,54
Jiló	Scarlet Eggplant	3.180,0	1363,4	42,88%	1.816,56
Limao	Lemon	180,8	129,7	71,70%	51,18
Manga	Mango	3.202,1	2124,9	66,36%	1.077,25
Pepino	Cucumber	3.432,2	1345,3	39,19%	2.087,02
Pimentao	Pepper	2.650,8	898,3	33,89%	1.752,57
Quiabo	Okra	4.628,7	2349,0	50,75%	2.279,70
Tomate	Tomato	8.403,8	2374,8	28,26%	6.029,03
Vagem	String bean	72,14	34,9	48,39%	37,23
Total		**28.856,9**	**12159,5**	**42,14%**	**16.697,42**

Source: Annual Inform CEASA,2017

As mentioned in section 4.1, several horticultural products grown in Itaocara are marketed in CEASA and distributed towards CEASA - Rio de Janeiro with 80% in the capital city and CEASA Sao Gonzalo and 20% covering cities such as Niteroi, Nova Friburgo, Teresópolis among others in the Central Region of the state. Some quantity is bought by wholesalers directly from farmers, who, in turn, distribute the horticultural products in the region or towards the capital as well.

The *Table 17* makes a comparison between the quantities that are produced by the municipalities according to the EMATER database and the quantities marketed by CEASA in 2017 according to the latest annual report.

Table 17: Comparison between Production and Marketing Process

Portuguese Name	English Name	Quantity Production (t)	Quantity marketed by CEASA - Itaocara (t)	Difference (t)	Proportion (%) Production/Marketing
Abobora	Pumpkin	60,0	49,6	10,441	83%
Abobrinha	Zucchini	87,3	81,8	5,41	94%
Aipim	Cassava	80,5	108,5	-28,048	-
Berinjela	Eggplant	973,0	1210,8	-237,804	-
Coco verde	Green coconut	169,8	64,5	105,262	38%
Goiaba	Guava	20,0	5,2	14,833	26%
Graviola	Soursop	3,0	18,7	-15,725	-
Jiló	Scarlet Eggplant	1547,0	1363,4	183,56	88%
Limao	Lemon	48,0	129,7	-81,675	-
Manga	Mango	1700,0	2124,9	-424,935	-
Pepino	Cucumber	603,5	1345,3	-741,76	-
Pimentao	Pepper	874,5	898,3	-23,78	-
Quiabo	Okra	2392,0	2349,0	42,955	98%
Tomate	Tomato	795,0	2374,8	-1579,812	-
Vagem	String bean	51,0	34,9	16,095	68%
Total		**9404,6**	**12159,5**	-2754,983	

Source: CEASA Annual Report 2017, EMATER Database 2017

As can be observed for most horticultural products, there is a correlation with initial information provided where more than 65% of the horticultural products are marketed by CEASA and it can be assumed that the rest is sold directly to wholesalers or delivered to schools through the PNAE program.

In addition, this comparison shows some inconsistencies in the food flow, given the greater quantity of marketed product versus the quantity of product produced. To clarify these uncertainties, several interviews were made in order to find out the cause of these differences but it was not possible to identify an answer, bearing in mind that both databases EMATER and CEASA are public and official reports.

b) National School Feeding Program – PNAE

A variety of foods produced in Itaocara are also consumed through the School Feeding Program. As mentioned in section 3.6 and 4.1, the PNAE purchases food produced in the municipality directly from farmers, for the provision of school meals in the public schools of Itaocara. According to the tender 002/2018 of the Municipality of Itaocara, it is estimated that the following amounts of food are consumed through the PNAE program per year:

Table 18: Quantity consumed by PNAE

Portugues Name	English Name	Quantity (t) PNAE
Abobora	Pumpkin	62,4
Abobrinha	Zucchini	0,00
Aipim	Cassava	39,0
Berinjela	Eggplant	0,0
Coco verde	Green coconut	0,0
Goiaba	Guava	52,0
Jiló	Scarlet Eggplant	0,0
Limao	Lemon	0,0
Manga	Mango	0,0
Pepino	Cucumber	0,0
Pimentao	Pepper	5,2
Quiabo	Okra	0,0
Tomate	Tomato	62,4
Vagem	String vean	20,8
Total		**241,8**

Source: Prefeitura Municipal de Itaocara

The fruits and vegetables consumed through the PNAE are around 499 tons/year consisting of other foods such as orange, passionfruit, banana, potatoes, cabbage among other products that are produced in very few quantities in Itaocara and are generally acquired from others municipalities.

Within the PNAE tender, the consumption of foods that are produced in Itaocara in important quantities such as Quiabo, Scarlet Eggplant or Manga are not reflected.

c) The Food Bank

In the horticultural flow, it is possible to show the role played by the Food Bank. As mentioned in section 3.6, the Food Bank through the PAA purchases fruits and vegetables that are not sold in CEASA. This means, food that was brought by farmers for marketing in CEASA but for reasons of price, quantity of buyers, market situation and demand were not sold.

The Food Bank buys the products at established prices and farmers does not lose their harvest. Different philanthropic institutions take the foods, thus avoiding the food waste. During the year 2017, the amount of food purchased and distributed by the Food Bank is presented in the *Table 18:*

Table 19: Quantity of horticulture products delivered to Food Bank 2017

Portuguese Name	English Name	Total Quantity CEASA (t)	Quantity delivered to Food Bank (t)	Proportion of Waste food used by Food Bank
Abobora	Pumpkin	99,71	5,182	5,20%
Abobrinha	Zucchini	163,24	0,332	0,20%
Aipim	Cassava	219,36	0	0,00%
Berinjela	Eggplant	2.504,19	10,256	0,41%
Coco verde	Green coconut	89,96	0	0,00%
Goiaba	Guava	6,34	11,576	182,67%
Graviola	Soursop	23,26	0,662	2,85%
Jiló	Scarlet Eggplant	3.180,00	0,389	0,01%
Limao	Lemon	180,85	13,32	7,37%
Manga	Mango	3.202,19	15,005	0,47%
Pepino	Cucumber	3.432,28	4,356	0,13%
Pimentao	Pepper	2.650,85	3,158	0,12%
Quiabo	Okra	4.628,74	1,511	0,03%
Tomate	Tomato	8.403,85	2,101	0,03%
Vagem	String bean	72,14	0	0,00%
Total		**28.856,96**	**67,848**	**0,24%**

Source: CEASA,2017

The 0,24% of the food that farmers did not sell in the CEASA point is used by the Food Bank for donation. Only one important difference in the amount of Goiaba is highlighted because the majority is purchased directly by Food Bank from Goiaba producers and it is not reported as income in CEASA.

It should be clarified here that the food bank also bought several amounts of food which is not the focus of this study, such as Avocado, Pineapple, Banana, Corn, among others. **In 2017 the food bank donated 135 tons of food.**

Marketing of milk is done directly by CAPIL and another dairy association in Northwest region (NWR). As mentioned in section 4.1, CAPIL is the cooperative responsible for the collection, processing, and sale of milk produced in the municipality. This commercialisation is shown in the table below.

Table 20: Dairy Marketing 2016

Dairy Marketing	Quantity (L)	Proportion over Total Production
Trade made by CAPIL Itaocara	25.892.112	21%
Trade made by Another dairy association	97.063.089	79%
Sold to Barra Mansa for long-life milk production	83.767.155	70%
Sol to NESTLE® - Tres Rios	35.206.486	30%
Production of cheese and butter in CAPIL Itaocara	1.553.527	6%*

Source: CAPIL

*Proportion over Trade made by CAPIL Itaocara

It is important to note here, that the CAPIL members belong to different municipalities. About 48% of the milk purchased by CAPIL comes from Itaocara and the rest from the other neighboring municipalities.

4.2.4 Food Consumption Process

According to the IBGE, Brazil has a food diet based on the traditional consumption of rice and beans, low in nutrients and high in calories mainly due to the consumption of sugars, soft drinks, animal fats and highly processed foods.

Of the total calories consumed by the population in Brazil, 57.6% comes from carbohydrates, 11.9% from protein consumption and 30.5% from lipid consumption.

The Nutritional Food Profile of Brazil reported by FAO shows that the diet of the population is based on the consumption of important quantities of cereals (35%), fats (15.7%), vegetables (2.2%), fruits (0.9%) and (6.6%) dairy consumption.

The research of family budgets carried out by the IBGE - Pesquisa de Orçamentos Familiares 2008-2009 - shows the per capita consumption of food in the state of Rio de Janeiro. With this, it is possible to determine the consumption of the horticultural flows in Itaocara as shown below

Table 21: Consumption of Horticultural Products in Itaocara

Portuguese Name	English Name	Consumption per capita /year (kg)	Consumption Itaocara (kg): Population 22.694 Inhab/2017	Consumption Itaocara 2017 (t)
Abobora	Pumpkin	14,9	338.594,5	338,6
Abobrinha	Zucchini	4,3	98.492,0	98,5
Aipim	Cassava	10,1	229.663,3	229,7
Berinjela	Eggplant	3,6	81.471,5	81,5
Coco verde	Green coconut	11,3	255.761,4	255,8
Goiaba	Guava	3,0	68.082,0	68,1
Graviola	Soursop	3,7	84.421,7	84,4
Jiló	Scarlet Eggplant	2,7	61.954,6	62,0
Limao	Lemon	5,8	130.944,4	130,9
Manga	Mango	11,9	268.923,9	268,9
Pepino	Cucumber	2,8	63.997,1	64,0
Pimentao	Pepper	6,8	153.865,3	153,9
Quiabo	Okra	2,7	60.139,1	60,1
Tomate	Tomato	43,3	983.331,0	983,3
Vagem	String bean	3,5	78.521,2	78,5
Total			**2.958.162,9**	**2.958,2**

Source: Own Elaboration based on IBGE - Pesquisa de Orçamentos Familiares 2008-2009

The same calculation for the Rio de Janeiro city is around: 2.084.287,0 ton. It is de total demand of fruits and vegetables.

It is also necessary to establish the amounts distributed by the Food Bank and by PNAE, for the general analysis in the consumption process in the food flow.

The products purchased by the Food Bank are donated to 29 philanthropic institutions located in different municipalities, not only in Itaocara. *Table 22* shows this distribution in 2017:

Table 22: Distribution of foods by Food Bank 2017

Municipality	Quantity donated by Food Bank (t)	No. Of philanthropic institutions
CEASA - Rio de Janeiro	85,8	1
CEASA - Sao Gonzalo	2,8	1
Sao José de Ubá	2,0	1
Trajano de Moraes	5,5	2
Itaocara	3,7	3
Sao Fidelis	10,2	5
Aperibé	2,5	1
Cambuci	2,3	2
Cordeiro	3,4	2
Italva	1,3	1
Cantagalo	7,3	3
Macaé	0,1	1
Campos dos Goytacazes	0,8	1
Sao Sebastian do Alto	3,3	1
S.M: Madalena	2,5	3
Macuco	0,7	1
Total	**135,0**	**29**

Source: CEASA,2017

Similarly, the consumption of food purchased by the PNAE is made in 55 public schools of Itaocara, serving a population of 1913 students.

The consumption of Dairy Flow was identified taking into account the IBGE Consumption Report from 2008-2009. The per capita consumption of dairy products in the State of Rio de Janeiro was 40,8 kg/year (IBGE, 2010), equal to 42 litres/year (the milk density corresponds to 1,03 litres of milk/1kg). Using similar analogy, **the milk consumption in Itaocara was 954.090 litres with the estimated population in 2017.**

The main consumption of dairy products is given in **Rio de Janeiro City**, where according to its population, the consumption could be close to 672 million of litres. However **the Northwest region only supplies 103.817.646 litres of dairy products.**

4.2.5 Food Wastage

For Horticultural and Dairy Flows, an accurate accounting and measurement of food waste in the analysis of food flow demands a detailed exercise and monitoring of the quantities of food that are not consumed or that lose their quality during each metabolic flow process. This is in addition to other factors such as time, human, economic resources, and information availability. Based on this and for the analysis carried out in this work, the reports of food waste by FAO was considered. The Global Food Waste in 2011 shows the food waste in each process of the Food Flow in Latin America is as shown in the table below.

Table 23: Food Waste in Food Flows

Food Flow	Production Process	Transport Process	Marketing Process	Consumption Process
Fruits and Vegetables	20%	12%	20%	10%
Dairy	3,5%	8%	2%	4%

Source: FAO,2011

This data is used for the determination of food waste in Itaocara, given that the amount of waste is determined according to the production, transport, marketing and consumption of fruits, vegetables and dairy products in the normal diet in Brazil.

Table 24: Food wastage calculation for each metabolic process

Food Flow	Production Process		
	Food Waste average	Quantity 2017	Food Waste
Fruits and Vegetables (t)	20%	12.400,6	**2.480,1**
Dairy (L)	3,50%	127.414.716	**4.459.515**

Food Flow	Transport Process		
	Food Waste average	Quantity 2017	Food Waste
Fruits and Vegetables (t)	12%	29.097,6	**3.491,7**
Dairy (L)	8,00%	122.955.20	**9.836.416**

Food Flow	Marketing Process		
	Food Waste average	Quantity 2017	Food Waste
Fruits and Vegetables (t)	20%	28.856,6	**5.771,3**
Dairy (L)	2,00%	121.401.674	**2.428.033**

Food Flow	Consumption Process		
	Food Waste average	Quantity 2017	Food Waste
Fruits and Vegetables (t)	**10%**	29.097,6	**2.909,8**
Dairy (L)	**4,00%**	**109.137.225**	**4.365.489**

Source: Own Elaboration

The total food waste for the food flows is:

Food Flow	Food Waste 2017
Fruits and Vegetables (t)	**14.652,9**
Dairy (L)	**21.089.454**

In the dairy flow the loss of raw milk before its commercialisation is caused by the presence of diseases in animals, such as mastitis or the use of antibiotics, which causes milk produced by the animal to be discarded immediately. In the case of large milk producers, this waste is estimated at about 2% of monthly production.

In the case of dairy waste in CAPIL, the company reports a loss of about 49000 litres per month, mainly due to quality aspects. This figure is included in food wastage in whole marketing process.

During the milk collection the cooperative driver takes a milk sample from each collection point, these samples are stored for 24 hours in the quality laboratory so that if there is an unusual situation during the analysis of the milk, it is possible to trace the origin of the contaminated milk.

In the process of pasteurisation and preparation of cheeses and butter, constant effort is made to guarantee the quality of the products and obtain the minimum waste by CAPIL. However, in some processes, the safety is lost due to infrastructure conditions, equipment and materials, which presents a very crucial challenge for the cooperative.

Some waste by CAPIL and fruits and vegetables are also used by other farmers generally for animal feeding, such as pigs. In other instances, the food waste is deposited in the landfill of the city. However, for Itaocara there is a storage area for all solid waste generated in the city, where only plastic separation is carried out by informal workers.

4.2.6 **Food Stocks**

In the analysis of urban metabolism, the stocks of materials within the different processes that make up the flows constitute a very important aspect. Usually, the stocks are given by the infrastructure, machinery, equipment and construction materials. Nevertheless, the stocks in the dairy and horticulture flows are identified during the production process in the form of raw material, and during marketing in CEASA and CAPIL respectively. However, these stocks are less than two days, as the horticultural and dairy food is highly perishable in addition to exposure to a tropical climate.

Given the above condition the analysis of this work that takes into account the annual food flows, and the inventory of the stocks is not considered.

4.3 Inputs and Outputs Related to Food Value Chain

4.3.1 Water Consumption

In Itaocara, 82% of the population (18,833 inhabitants) have access to potable water supply through a network of 73 Km of pipes in 5 districts.

The CEDAE company is responsible for the water distribution through 10 pumping stations located in the Paraiba River basin. The water is then taken to a treatment plant where the processes of sulphation, flocculation, decantation, filtration, and chlorination are carried out to guarantee a quality supply of 65L/s of drinking water.

Water distributed mainly for urban areas for domestic use is about 95%, 2% for industrial use (Construction projects), and 3% for commercial use. The cost of access to drinking water service is around BRL 42 (EUR 9.2) / 15,000 L/month. This service is however free in hospitals and public schools.

Table 25: Water Consumption Itaocara

Water consumption	213,8 L per-capita/day
Freshwater Supply	5’616.000 L/day
Freshwater Consumption	4’011.429 L /day

Source: Prefeitura Municipal Itaocara, 2012

With respect to access to water for agricultural activities, farmers usually make "açudes" or wells from natural springs, rainwater, nearby lakes or streams. It is used for the irrigation, feeding and care of animals. 98% of farmers use these "açudes", but the other percentage also makes use of underground wells that are installed and operated by farmers themselves. In both cases, unfortunately the INEA does not have an exact information of its quantity and supply capacity.

Image 6: Açudes - Wells in Itaocara
Source: Own Photography

With the support of the technicians of PESAGRO, EMATER and the field visits, the following approximations were made in order to estimate the water consumption for the dairy and horticulture flows:

- Water is more than 90% of the weight of the usable fresh material in most fruits and vegetables (Universidade Federal Viçosa, 2008). It is the reason because FAO considers that 59% of water consumption is given by agricultural activities.

- In Itaocara, 70% of the farmers use three methods for the irrigation of crops. These are sprinkle irrigation, surface irrigation and drip irrigation. The first two methods leads to greater waste according to the topographic conditions, where the water runoff does not allow for uptake by the crop. However, the sprinkle method is more used because it requires less labour with regard to surface or drip irrigation. Sprinkle method is mainly used for the cultivation of pastures. For fruits and vegetables, the producers prefer the drip system. The remaining 30% of the producers that do not have irrigation systems use manual irrigation, plant by plant.

- To estimate the average water consumption per crop, a planting area of 1 ha of tomato was used as a basis for estimation where the following variables were taken into consideration.

    - The production of 11,000 tomato plants per 1 ha.
    - According to each stage during the growth cycle, from planting to harvest and depending on its size, the water consumption varies. It is estimated that with a drip

irrigation system one plant consumes 770 litres of water during a cycle of 150 days, with an average water consumption of 7 mm/day.

- This means 11,000 tomato plants on a 1-hectare field will consume 8470 m^3 of water in a 150-day cycle.
- The tomato plantations in Itaocara are generally outdoors, with an efficiency of 58 tons per hectare.
- Taking into account that 795 tons of tomatoes was produced in Itaocara in 2017, it is possible to estimate that:

58 tons of tomato grown on 1 hectare consume 8470 m^3 of water during its 150-day cycle.

Or with the tomato production data in Itaocara in 2017:

795 tons of tomato grown on 13,5 hectares consumed 116097,4 m^3 of water

Water productivity: 6,84 kg/m^3

Given the above example, calculating of the water consumption for each of the crops described in this thesis work depends on several variables such as weather, precipitation, topography, type and texture of the soil, irrigation system, availability of water in the soil among others, It is therefore very difficult to do a real calculation about water consumption or water productivity in crop production. Nevertheless, a close approximation is shown on *Table 26* below based on a bibliography review regarding water productivity.

Table 26: Water Consumption in Production Process

Portuguese Name	English Name	Water Productivity kg/m3	Production Quantity (kg)	Water Consumption (m^3)	Bibliography	Data Quality
Abobora	Pumpkin	0,7	60.000	85.714	Necesidades hídricas de Cultivos intensivos, 2015. http://www.fagro.edu	Non accuracy data: Water Productivity for small vegetables production
Abobrinha	Zucchini	0,7	87.250	124.643	Necesidades hídricas de Cultivos intensivos, 2015. http://www.fagro.edu	Non accuracy data: Water Productivity for small vegetables production
Aipim	Cassava	10,5	80.500	7.667	Revista ciencias técnicas agropecuarias. Instituto Superior de Ciencias Agropecuarias de la Habana, 2014.	Stable accuracy data: Research
Berinjela	Eggplant	0,7	973.000	1.390.000	Necesidades hídricas de Cultivos intensivos, 2015. http://www.fagro.edu	Non accuracy data: Water Productivity for small vegetables production
Coco verde	Green coconut	-	169.800	-	-	-
Goiaba	Guava	0,51	20.000	39.370	Respuesta productiva del guayabo al manejo del agua en condiciones de agricultura urbana. Centro de Mecanización Agropecuaria,2010.	Non accuracy data: Data Calculation based on other research.

Graviola	Soursop	-	3.000	-	-	-
Jiló	Scarlet Eggplant	0,7	1.547.000	2.210.000	Necesidades hídricas de Cultivos intensivos, 2015. http://www.fagro.edu	Non accuracy data: Water Productivity for small vegetables production
Limao	Lemon	0,76	48.000	63.158	Respuesta del rendimiento de los cultivos al agua. FAO,2012 www.fao.org	Stable accuracy data: Research
Manga	Mango	-	1.700.000	-	-	-
Pepino	Cucumber	1,3	603.500	464.231	Riego en cultivos de alto rendimiento-Hortalizas. Flores Velázquez,J., 2015. https://www.hortalizas.com	Stable accuracy data: Research
Pimentao	Pepper	0,67	874.500	1.305.224	Riego en cultivos de alto rendimiento-Hortalizas. Flores Velázquez,J., 2015. https://www.hortalizas.com	Stable accuracy data: Research
Quiabo	Okra	0,7	2.392.000	3.417.143	Necesidades hídricas de Cultivos intensivos, 2015. http://www.fagro.edu	Non accuracy data: Water Productivity for small vegetables production
Tomate	Tomato	6,84	795.000	116.097	Data calculation made in field with support of EMATER	Stable accuracy data: The research by Florez Velazquez shows a Water productivity of 7,2 kg/m3. However, It is taken in account the calculation results made in Itaocara.
Vagem	String bean	0,7	51.000	72.857	Necesidades hídricas de Cultivos intensivos, 2015. http://www.fagro.edu	Non accuracy data: Water Productivity for small vegetables production
Total			9.404.550	**9.296.103**		

Source: (Centro de Mecanización Agropecuaria, Instituto Superior de Ciencias Agropecuarias de la Habana., López Seijas, & Cid Lazo, 2014; FAO, 2012; Flores Velázquez, 2015; Universidad de la Republica, 2015)

Regarding water consumption in the dairy flow, the information provided by PESAGRO in Itaocara was taken into consideration. According to PESAGRO Research Centre located in Itaocara, the average water consumption just for the care and feeding of dairy cattle is 32,3 liters of water per liter of raw milk produced, and with available data for raw milk production, it is possible to affirm that:

The dairy production in Itaocara consumed 366230,9 m^3 of water in 2017 and 389793,9 m^3 of water in 2016.

This calculation does not take into account the consumption of water for irrigation of grasslands.

For water consumption during processes of pasteurisation and manufacturing of derivative products such as milk, butter, and cheese, CAPIL reports an average water consumption of 3571.4 m^3/month or annually of 42856, 8 m^3 of water.

4.3.2 **Energy Consumption**

The consumption of energy is a key indicator for the study of urban metabolism, given that the analysis of energy flow is one of its conceptual bases. Nevertheless, the data calculations for energy consumption and transformation during each one of the activities developed in each process in the Food flow is a real challenge for researches using the urban metabolism approach. Consequently, the exact data of energy consumption as income to the system exceed the scope of this study. However, it is possible to describe the energy flow in a qualitative form for the dairy and horticulture flows.

The consumption of energy has not stopped to grow since the invention of fire. This consumption is increasing mainly due to industrial activities, agriculture, and transport (Albeiro, 2014). According to the Energetic Balance of Brazil developed in 2016, the agricultural sector consumes 3.6% of the energy produced, which in terms of energy units is around 119 Million MWh (10291 Ton Oil Equivalent.) (Ministerio de Minas y Energía Brasil, 2016). This consumption is higher than the 94 Million MWh that is produced by the second largest hydroelectric power plant in the world.

According to the consulted bibliographic sources, the flow of energy in agriculture can be represented by the model shown below.

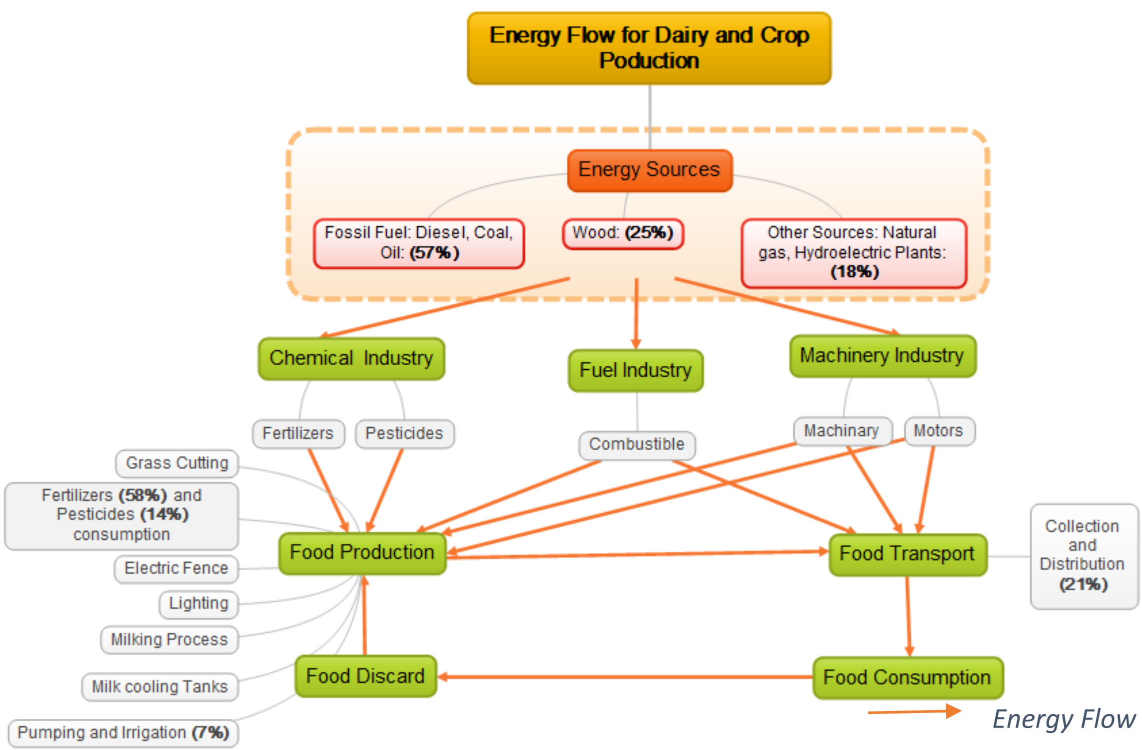


Figure 22:Energy Flow for Dairy and Crop Production
Source: Own Elaboration based on BEN 2016

Brazil in recent years has been identified as an important producer of biofuels. However, the agricultural sector depends to a large extent on fossil sources (57%), which can be contradictory. This phenomenon is explained in the use of internal combustion machinery during the production process and also by the use of fuels during the transport process.

As observed during the flow of energy, the production process has the highest energy consumption, mainly in the activities of soil preparation use of fertilisers and pesticides with the understanding that the last activity also uses machinery and internal combustion motors, as well as for the irrigation activity.

According to the Brazilian legislation, there are different groups in the energy supply tariff. With respect to agricultural activities, there is a reduction of up to 59% over the total value with a different tariff for the electricity service used for irrigation activities.

Energy Consumption during Production Process

To establish the energy consumption within the production process in food flows, different variables such as energy source, type of energy, irrigation system, machinery, fuels, among others must be considered. Similar to the calculation of water consumption, in this study, an approximation to energy consumptions is made taking into account a bibliographic review as shown below.

Table 27: Energy Consumption in Production Process

Portuguese Name	English Name	Energy Productivity kg/kWh	Crop Productivity kg/ha	Production Quantity (kg)	Energy Consumption (kWh)	Bibliography	Data Quality
Abobora	Pumpkin	7,6	12.500,0	60.000	7.894,7	La eficiencia energética en la agricultura de conservación frente a la agricultura tradicional.Arrúe, Fuentes, & Martinez, 2013	Stable accuracy data: The calculations are made taking into account the reference of 1638.84 kWh/ha and the productivity of each crop (kg/ha)
Abobrinha	Zucchini	6,9	11.258,1	87.250	12.701,5	La eficiencia energética en la agricultura de conservación frente a la agricultura tradicional.Arrúe, Fuentes, & Martinez, 2013	Stable accuracy data: The calculations are made taking into account the reference of 1638.84 kWh/ha and the productivity of each crop (kg/ha)
Aipim	Cassava	0,6	13.416,7	80.500	139.756,9	estudio aparte	
Berinjela	Eggplant	12,4	20.270,8	973.000	78.667,2	La eficiencia energética en la agricultura de conservación frente a la agricultura tradicional.Arrúe, Fuentes, & Martinez, 2013	Stable accuracy data: The calculations are made taking into account the reference of 1638.84 kWh/ha and the productivity of each crop (kg/ha)
Coco verde	Green coconut	-	17.873,7	169.800	-	-	-
Goiaba	Guava	-	13.333,3	20.000	-	-	-
Graviola	Soursop	-	2.000,0	3.000	-	-	-
Jiló	Scarlet Eggplant	14,7	24.171,9	1.547.000	104.889,6	La eficiencia energética en la agricultura de conservación frente a la agricultura tradicional.Arrúe, Fuentes, & Martinez, 2013	Stable accuracy data: The calculations are made taking into account the reference of 1638.84 kWh/ha and the productivity of each crop (kg/ha)

Limao	Lemon	1,9	16.000,0	48.000	25.263,2	Análisis enérgetico de los principales cultivos de la región de Murcia. Ángel Martínez, Martín Górriz, & Martínez Álvarez, 2012	Stable accuracy data: The calculations are made taking into account the reference of 0,5277 kWh/kg
Manga	Mango	-	20.000,0	1.700.000	-	-	-
Pepino	Cucumber	21,7	35.500,0	603.500	27.861,3	La eficiencia energética en la agricultura de conservación frente a la agricultura tradicional.Arrúe, Fuentes, & Martinez, 2013	Stable accuracy data: The calculations are made taking into account the reference of 1638.84 kWh/ha and the productivity of each crop (kg/ha)
Pimentao	Pepper	14,8	24.291,7	874.500	59.000,4	La eficiencia energética en la agricultura de conservación frente a la agricultura tradicional.Arrúe, Fuentes, & Martinez, 2013	Stable accuracy data: The calculations are made taking into account the reference of 1638.84 kWh/ha and the productivity of each crop (kg/ha)
Quiabo	Okra	8,1	13.288,9	2.392.000	295.002,0	La eficiencia energética en la agricultura de conservación frente a la agricultura tradicional.Arrúe, Fuentes, & Martinez, 2013	Stable accuracy data: The calculations are made taking into account the reference of 1638.84 kWh/ha and the productivity of each crop (kg/ha)
Tomate	Tomato	3,2	58.888,9	795.000	248.437,5	Balance de energía en cultivos hortícolas a campo en Rosario,Argentina. Universidad Nacional de Entre Ríos,2010	Stable accuracy data: Research
Vagem	String bean	10,4	17.000,0	51.000	4.916,7	La eficiencia energética en la agricultura de conservación frente a la agricultura tradicional.Arrúe, Fuentes, & Martinez, 2013	Stable accuracy data: The calculations are made taking into account the reference of 1638.84 kWh/ha and the productivity of each crop (kg/ha)
Total				9.404.550	**1.004.391**		

Source: (Ángel Martínez, Martín Górriz, & Martínez Álvarez, 2012; Arrúe, Fuentes, & Martinez, 2013; Manzanares, 1997; Universidad Nacional de Entre Ríos, 2010)

In the case of Dairy production, based on the observation made in the field and interviews carried out. The cooling process in the tank accounts for the higher energy consumption. According to the milk production activities developed in the PESAGRO Research Center in Itaocara, it is established that the production of 1 litre of milk consumes an estimated of 0,065 kWh in accordance with variables such as livestock type, animal weight, milking, cleaning activities, cooling tank capacity among others. Using available data of milk production in Itaocara is estimated that:

In 2017, dairy production in Itaocara consumed **740800 kWh** and **785000 kWh** in 2016.

The energy source used by CAPIL for its transformation processes comes from the consumption of $1000 m^3$ of wood annually[10], which is transformed through a steam boiler of 6 m that generates 2,500 kg of steam/hour or 225 kWh. CAPIL works every single day for 12 hours, bringing the consumption of energy by CAPIL to an estimated 972000 kWh.

Energy Consumption during Transport Process

The consumption of energy in the transport of food is one of the most representative aspects in the analysis of food flow, these were estimated taking into account the following assumptions:

- Fuel Efficiency of a truck = 3 km / liter of diesel (Horticultural Flow)
- Fuel Efficiency of a truck with capacity 10,000 liters = 2,5 km / liter of diesel (Dairy Flow)
- The conversion of liters to gallons of Diesel is: 1 l = 0,26 gal
- The conversion of diesel to kWh is: 1 gal diesel = 40,7 kWh

Table 28: Energy Consumption in Transport Process

Main distances in Horticulture Flow				Efficiency of track (gal/km)	Diesel Consumption (gal)	Energy Consumption kWh
Process	From	To	km			
Collection	Itaocara	CEASA Itaocara	13,6	0,087	1,17	47,97
	Itaperuna	CEASA Itaocara	98,8	0,087	8,56	348,50
	Sao Sebastian do Alto	CEASA Itaocara	26,2	0,087	2,27	92,41
	Macuco	CEASA Itaocara	47,4	0,087	4,10	167,19
	São Fidélis	CEASA Itaocara	38,3	0,087	3,31	135,09
	Santo Antônio de Pádua	CEASA Itaocara	35,4	0,087	3,06	124,86
	Cambuci	CEASA Itaocara	33,2	0,087	2,87	117,10
Distribution	CEASA Itaocara	CEASA Rio de Janeiro	253	0,087	21,92	892,41
	CEASA Itaocara	CEASA São Gonçalo	218	0,087	18,89	768,95
	Itaocara	CEASA Rio de Janeiro	266	0,087	23,05	938,27
Main distances in Dairy Flow				Efficiency of track (gal/km)	Diesel Consumption (gal)	Energy Consumption kWh
Process	From	To	km			
Collection	Aperibe	CAPIL Itaocara	6,1	0,104	0,63	25,820
	Cambuci	CAPIL Itaocara	22,9	0,104	2,38	96,931
	Cantagalo	CAPIL Itaocara	54,5	0,104	5,66	230,688
	Miracema	CAPIL Itaocara	39,2	0,104	4,0768	165,926
	Santo Antônio de Pádua	CAPIL Itaocara	23,6	0,104	2,4544	99,894
	São Fidélis	CAPIL Itaocara	51,9	0,104	5,3976	219,682
	Sao José de de Ubá	CAPIL Itaocara	58,2	0,104	6,0528	246,349
	Sao Sebastian do Alto	CAPIL Itaocara	39,3	0,104	4,0872	166,349
	Total distance travelled by 10 Tracks		**295,7**	**0,104**	**30,7528**	**1.251,639**
Distribution	CAPIL Itaocara	Barra Mansa	288	0,104	29,952	1.219,046

[10] Information given by CAPIL. They control the energy production with m^3 of Wood annually.

	CAPIL Itaocara	Nestle- Tres Rios	164	0,104	17,056	694,179
	Barra Mansa	Rio de Janeiro City	135	0,104	14,04	571,428
	Nestle- Tres Rios	Rio de Janeiro City	132	0,104	13,728	558,730

Source: CAMINOS Y PUENTES, 2004

The total calculation of energy consumption in the Horticulture flow was made based only on the distance between Itaocara (as a producer point) to the CEASA Itaocara (as marketing point) and from CEASA Itaocara to the longest sales distance in CEASA Rio de Janeiro. This total distance is 266,6 km.

Similarly, 3 tons was used as reference data for weight capacity of one truck with an estimated efficiency of 0,087 gal/km. **The transport of 12169 tons of horticultural products will therefore have an efficiency of 352,6 gal/km.**

Table 29: Energy consumption in horticultural products transport

Distance (km)		Total Efficiency of track (gal/km)	Diesel Consumption (gal)	Energy Consumption kWh
Itaocara – CEASA – Rio de Janeiro	**266,6**	**352,6**	**94003**	**3825928,6**

Source: Own elaboration

For the dairy flow, 10.000 litres was used as reference data for weight capacity of one truck with an efficiency of 0,104 gal/km.

The transport of 12.067.923 litres of raw milk from Itaocara in 2016 will therefore have an estimated efficiency of 125,5 gal/km.

Table 30: Energy consumption in dairy products transport

Distance (km)		Total Efficiency of track (gal/km)	Diesel Consumption (gal)	Energy Consumption kWh
Collection and distribution Process	**1014,7**	**125,5**	**127351,3**	**5183199,7**

Source: Own elaboration

4.3.3 CO2 Emissions

For the Outputs analysis in the food flows, is necessary to calculate the CO_2 emissions. This is done only for production and transport process, given the availability of information regarding electricity and fuel consumption.

In the production process, the number of tons of CO_2 is estimated taking into account the electricity consumption in units of kWh, using a unit converter.

The electricity Consumption in Production Process for horticultural flow was estimated at 1004391 kWh which equal to 82,7 Tons of CO_2

and

The electricity Consumption in Production Process for dairy flow was estimated at 785000 kWh equal to 64,6 Tons of CO_2, and the marketing process has an estimated consumption of 972000 kWh equal to 80 Tons of CO_2.

For the transport process, a value of 0,010 Ton of CO_2 was assumed for each gallon of diesel consumed, according to the literature review.

Table 31:CO2 Emission during Transport Process

Main distances in Horticulture Flow				Diesel Consumption (gal)	CO2 Emission (Ton eq. CO2)
Process	From	To	km		
Itaocara – CEASA – Rio de Janeiro			266,6	94003	**940**
Main distances in Dairy Flow				Diesel Consumption (gal)	**CO2 Emission (Ton eq.CO2)**
Process	From	To	km		
Collection and Distribution Process			1014,7	127351,3	**1340,5**

Source: www.cambioclimaticocr.com/calculadora-huella-carbono/index.php

4.3.4 Fertilizers and Pesticides

In Itaocara, 100% of the crops are grown using of fertilisers and "defenders" commonly called agrotoxins, agrochemicals or pesticides.

A production system based on 100% organic was not seen. In fact, this activity is not very well-known in Itaocara, because according to interviews with professionals, institutions and farmers, there is no market for organic crops. The economic situation forces the population towards consumption of foods conventionally produced. For this reason, they consider the organic agriculture as not profitable business. However, they are fully aware of its social and environmental importance.

With respect to the use of fertilisers, IBGE reported in 2014 an estimated 108.3 kg of (Nitrogen, Phosphorus and Potassium) per hectare cultivated in the state of Rio de Janeiro (IBGE, 2014). Assuming an equal consumption of fertilisers in 2017 with respect to the amount of hectares planted from the horticultural flows in Itaocara, it is possible to affirm that

In 2017. horticultural production on **477,5 hectares** consumed **51,7 tons of fertilisers**

The use of pesticides or agro-toxins, refers to herbicides, fungicides, insecticides, bactericides and growth regulators among others that are used massively by farmers for the control of pests, diseases and care of their crops. This is however despite the serious damage caused over water resources, loss of soil fertility, health risk for farmers due to direct contact and general health risk due to food consumption.

According to an IBGE report in 2001, the consumption of agro-toxins in Brazil was estimated around 3.13 Kg of agro-toxins per hectare of land planted (IBGE, 2004). Assuming a similar consumption of agro-toxin in 2017, it is possible to affirm that:

In 2017 alone, horticultural production on **477,5 hectares** consumed **1.49 tons of agro-toxins.**

5 Analysis and Discussion


Dairy Farm. Own Photography. 2018

"Todos los pueblos tenemos demonios, el truco es conjurarlos de una manera tal que no devasten al pueblo, que no le impidan salir adelante. Que se puedan manejar de una manera en que el progreso y la reconstrucción tengan posibilidades."

Diana Uribe

The food flow analysis represents an opportunity to improve global food availability, but also to mitigate environmental impacts and resources use along the food chain (FAO,2017). The analysis of dairy and horticultural flows is done through the MFA method. The results shown in the previous chapter are organized to identify the inputs and outputs that affect the Food Flows. Initially, the analysis of the Foodshed for dairy and horticultural flows allows the system boundaries visualization geographically. Then, Sankey diagrams presents the analysis of food flow with its inputs and outputs graphically, later the analysis of the Itaocara metabolic profile for the food flows, according to the indicators established by the MFA is presented.

Critical points within food flows allow the identification of the main challenges for primary and secondary stakeholders in the regional food value chain. These challenges are used to make some general recommendations that are presented at the end of this chapter.

5.1 System Boundaries Identification: Foodshed

From the Foodshed of food flows studied, it can be geographically observed how the flows are distributed from the production points to the consumption points, through the transport roads that communicate them.

Visually, the Foodshed allow identifying the quantities of food in each metabolic process geographically, becoming a tool for public decision making related to the food value chain in the Northwest region and in Itaocara.

In the Foodshed, it was identified that the quantity of fruits, vegetables, and dairy products in the Northwest region and especially in Itaocara exceed the food supply of its population and it is one of the main supply sources for the Rio de Janeiro city.

The Foodshed boundaries for horticultural and dairy products exceed the geopolitical boundary of Itaocara. The horticultural production is in most of the Northwestern region and even in other regions. Here, is the case of Sao Fidelis, which due to its proximity to Itaocara allows a strong food exchange between the Northwest region and Serrana region. Other municipalities in the Northern region as San Francisco de Itapoboana transport their production to Itaocara. It extends the foodshed to the Northern region. Municipalities such as Natividade and Porciuncula belong to the Northwestern region. However, they do not exchange their horticultural production with Itaocara. It is due to the distance given that they are located in the extreme north of the Northwestern region.

The 58% of the horticultural products that go inside the foodshed come from other municipalities - (36%) from the Northwest region and (22%) from other regions -, the remaining 42% comes directly from Itaocara.

The foodshed for dairy products was defined in the northern part exactly by the geopolitical boundaries of the Northwestern region of Rio de Janeiro state. However, the foodshed comprises the municipalities of Tres Ríos and Barra Mansa (South region), where CAPIL has marketing interrelations.

Both of foodsheds define their final consumption in the city of Rio de Janeiro. The capital city demands 5 times more than dairy production in the whole Northwestern region. This means; the Northwestern region supplies 19% of the demand for dairy products for the Rio de Janeiro city. Horticultural production in the Northwestern region just supplies 1% of the total demand for Rio de Janeiro city.

Nevertheless, Itaocara city covers the whole demand for horticultural and dairy products by both foodsheds.

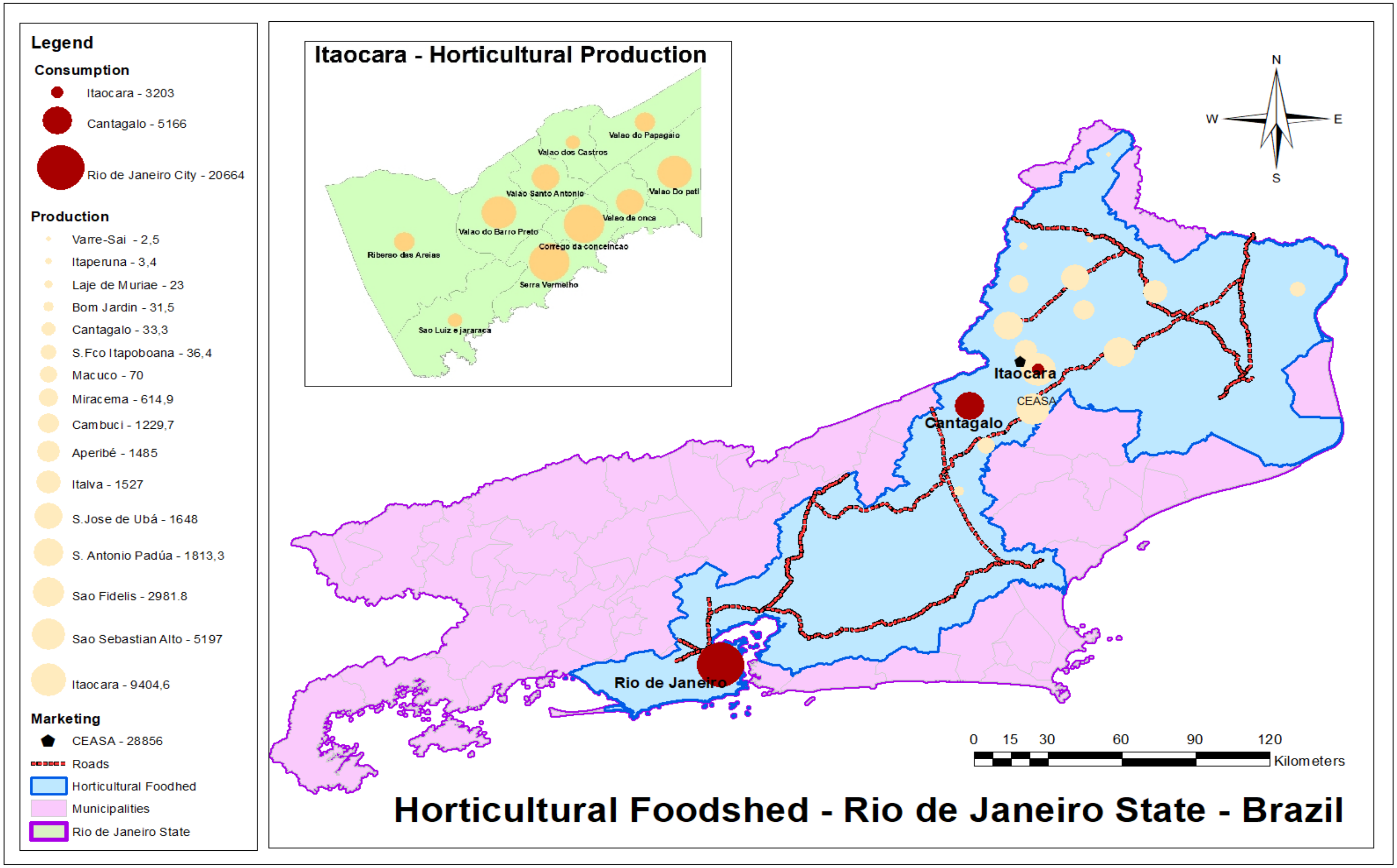


Figure 23: Foodshed for horticultural products
Source: Own elaboration

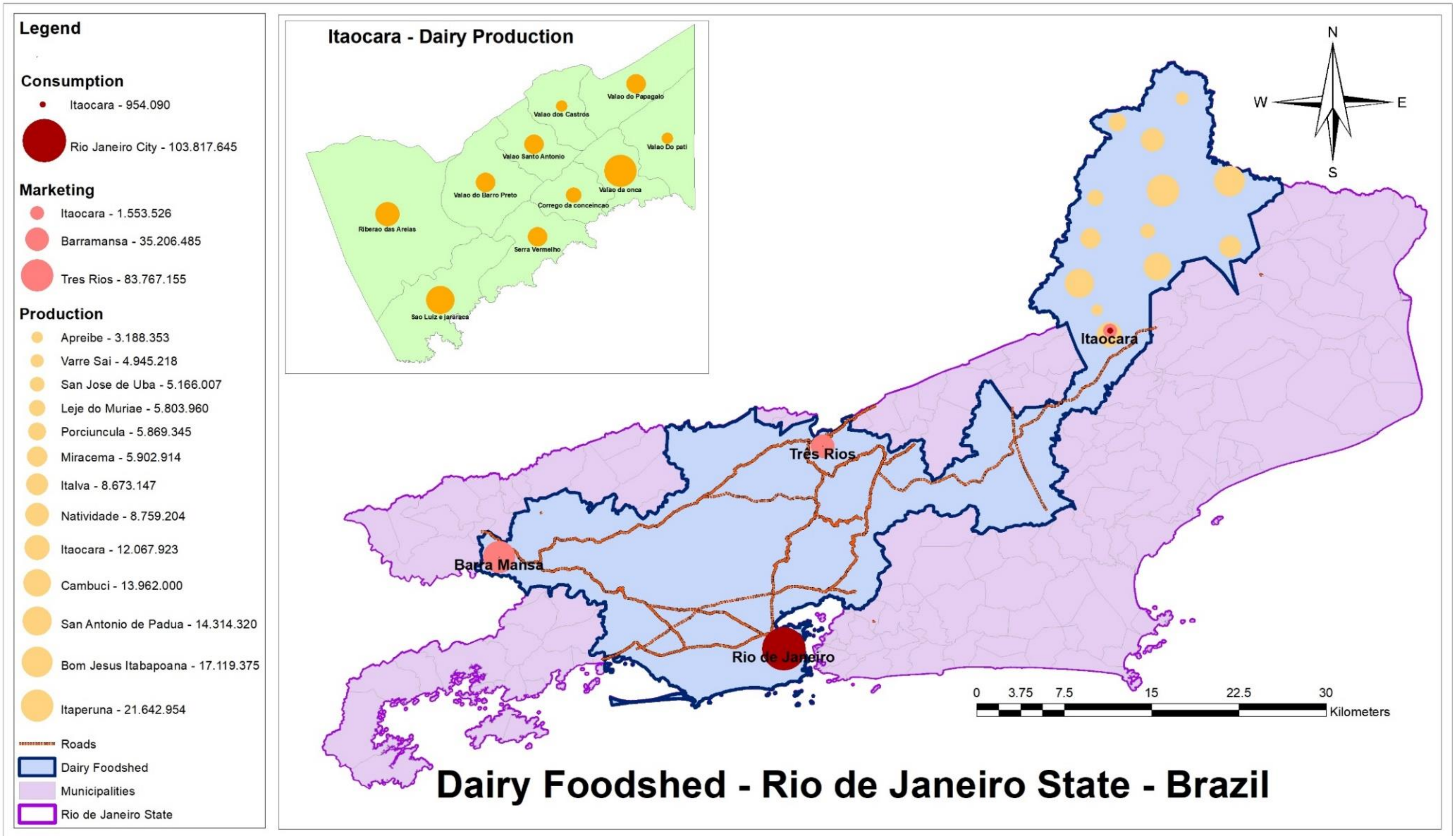


Figure 24: Foodshed for horticultural products
Source: Own elaboration

5.2 Material Flow Analysis

The Sankey diagrams show the food flows in each process, identifying the inputs and outputs, in terms of energy, water, amount of food, emissions, and food wastage. The diagrams were elaborated from the qualitative results of this research work. However, factors such as land use degradation, erosion or water waste were described qualitatively, and they are not considered within the numerical balance of the diagrams.

5.2.1 Sankey Diagram for Horticulture Flow

The general diagram identifies how the initial production volume is distributed along the flow, as well as how other factors and flows interact before reaching the final consumer. In the food flow, the following aspects are identified according to with each process:

There is an initial production of 12400 tons of food by the family farmers of Itaocara. This amount is divided between the food that is sold directly by the producers to the PNAE program, the food that is transported to CEASA, and the food wastage during the production process that is usually given by the presence of diseases in the crops or climatic conditions.

In addition to this production, 2755 tons are identified in the food flow that is reported in CEASA database as foods produced in Itaocara. However, this amount is not described in the EMATER food production databases. The result is therefore questionable, given that the exact origin of this quantity is unknown and is reported in the food flow as "surplus production". At this point, it is important to highlight that CEASA Itaocara is only allowed to commercialise the food produced in Itaocara and municipalities belonging to the state of Rio de Janeiro and it would be a serious public fault to commercialise products from other neighbouring states of Itaocara such as Mina Gerais because that would affect directly the food regional value chain.

The transport process is divided into two parts; first from the production by family farmers to CEASA Itaocara and the other from CEASA Itaocara to other distribution or commercialization points. This process is mainly affected by the consumption of energy (Diesel) and the resulting CO_2 emissions. Another important output is the food waste that occurs mainly due to weather conditions, where the vehicles that transport food do not have food cooling systems, products are exposed to the tropical conditions of the region, also taking into account the long distances from the production to consumption such as in CEASA Rio de Janeiro in the capital city. In some cases, the loss is also due to issues related to food packaging.

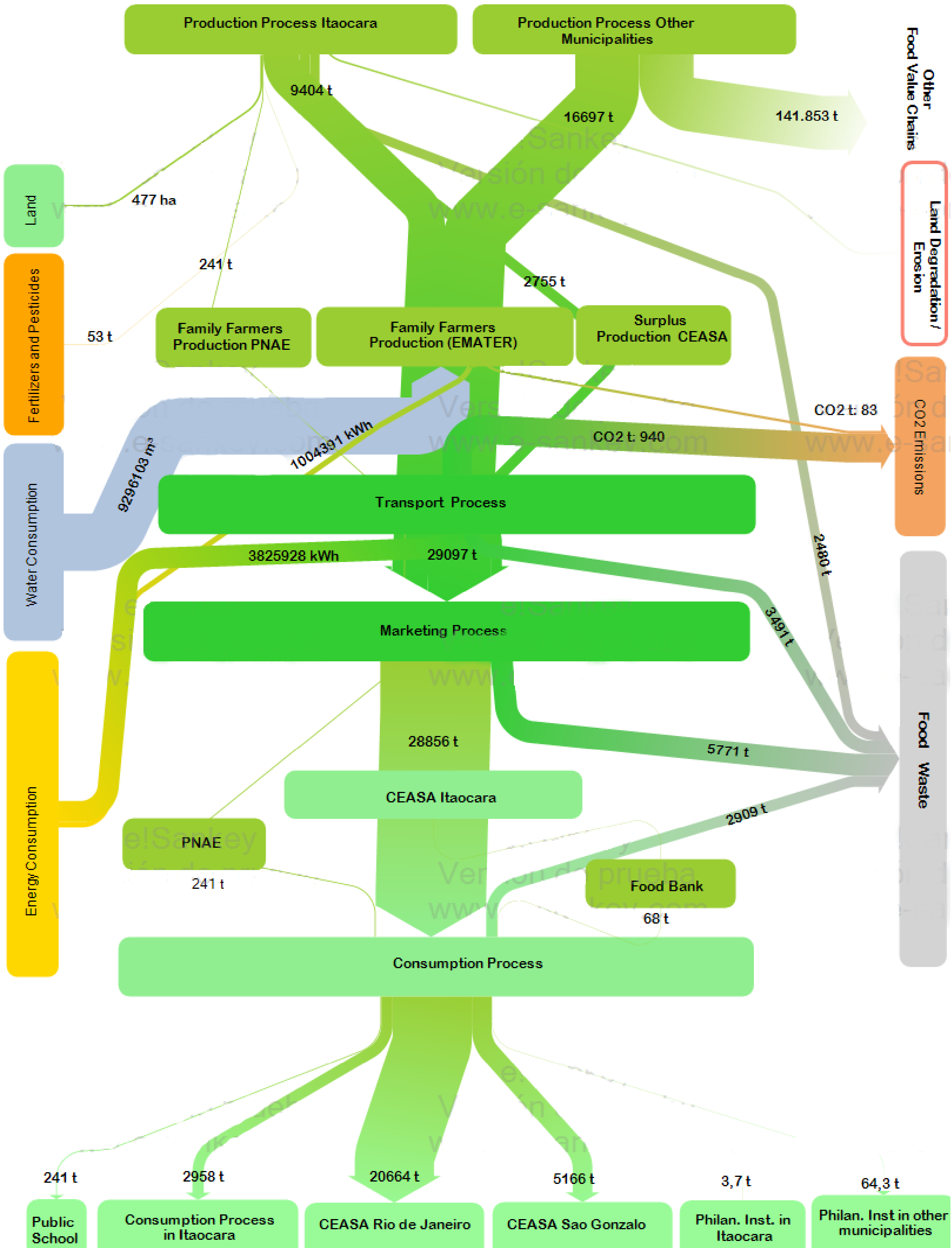


Figure 25:Sankey Diagram for Horticulture Flow
Source: Own Elaboration. Free trial License by e!Sankey 2018.

The marketing process takes place through three channels as described earlier. However, in the food flow, it is observed that the most important channel is the point of marketing in CEASA. It is a critical point within the flow, given that at this point arrives foodstuffs from other municipalities and the food is distributed throughout the region, mainly to the city of Rio de Janeiro. CEASA is the core of the relationships between producers, wholesalers, consumers, and transporters, consisting of all the actors within the food flow converge in CEASA, which makes it an important point of action and relevance.

This process also presents a significant amount of food wastage, usually given by products that are not marketed, for reasons such as lack of buyers, quality of products, market conditions like low prices and high supply among others. However, this figure is reduced by the role played by the Food Bank. It is also supplied by other food flows in order to make food donations to philanthropic institutions in Itaocara and other municipalities. The third marketing channel is the PNAE. It shows a considerable flow of food, which can be much greater given the wide and diversified offer of family farming.

Although the flow of food distributed by the PNAE is important, it represents only 19% of the purchases made by the national government to the production of family farming (PAA Program), when the Law No. 11947/2009 establishes that these purchases must be of minimum the 30%. This way, the projection of family agricultural production increases in Itaocara.

The most important consumption of horticultural foods produced in Itaocara occurs in other regions, mainly in the city of Rio de Janeiro, through wholesalers who deliver the foodstuffs to the supply point in CEASA Rio de Janeiro.

On the other hand, it was also identified that the demand for fruits and vegetables in Itaocara is supplied by their production. This means; that Itaocara does not necessarily need to import from other municipalities horticultural products to feed its population.

During the consumption process, there is also food wastage, mainly during the preparation of food in homes, where food or part of these are discarded by aesthetic conditions or during consumption generally by diet and/or consumer preferences, where the consumption of fruits and vegetables is quite low and the highest energy supplement is given by the rice and wheat consumption.

5.2.2 **Sankey Diagram for Dairy Flow**

The Dairy Flow starts with the production of 127.414.716 liters of milk in the Northwest region, of which 9% is produced in Itaocara and the rest in municipalities such as Itaperuna, Cambuci and Padua.

The raw milk marketed through the association CAPIL in Itaocara is 20% of the total production in the Northwest region. The 80% is marketed through other Dairy Associations. The family farmer of dairy products can belong to several cooperatives and according to the purchase price of raw milk, sell their production where they so desire.

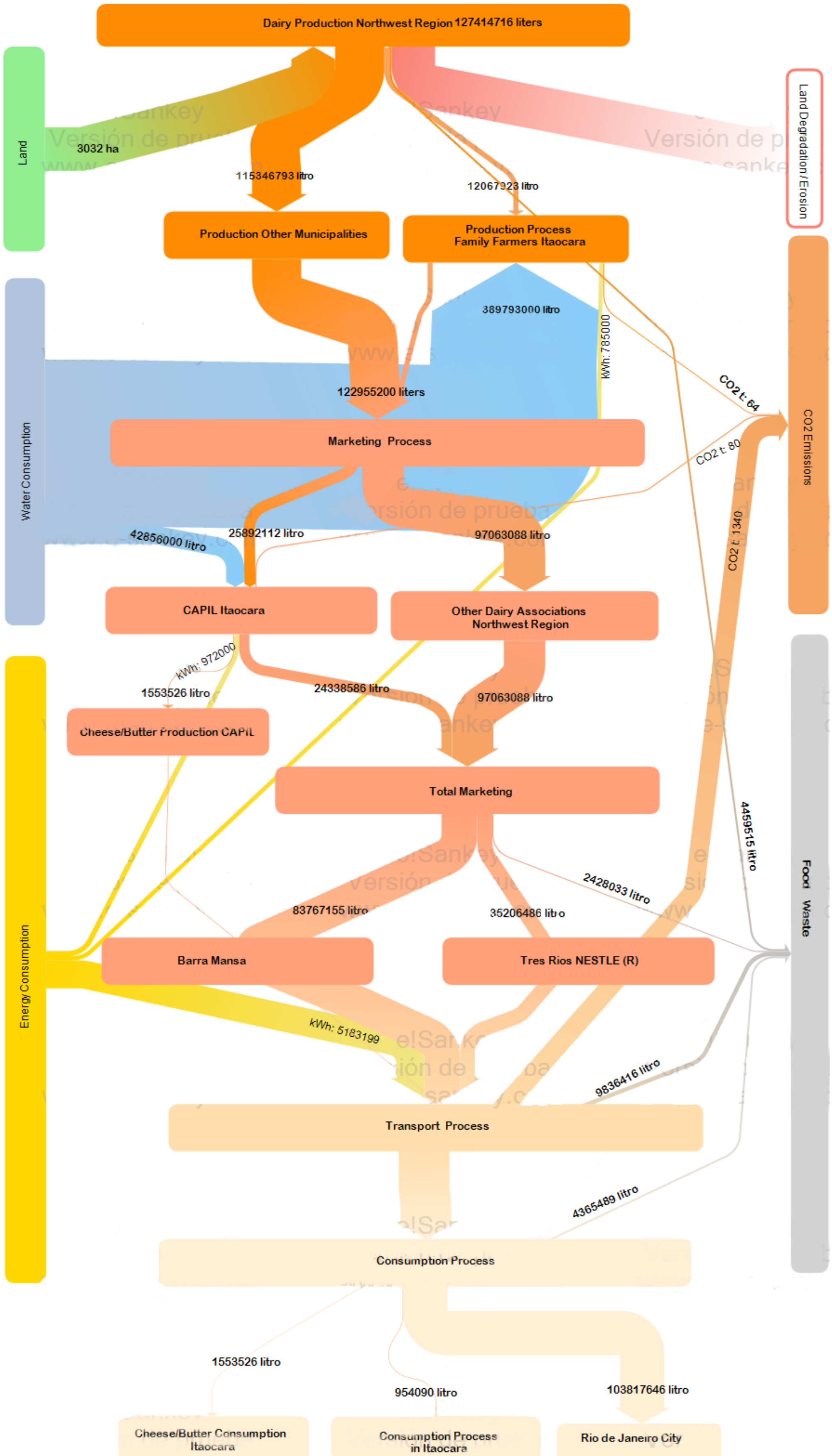


Figure 26: Sankey Diagram for Dairy Flow
Source: Own Elaboration. Free trial License by e!Sankey 2018.

The Itaocara raw milk production is sent to two points in the Southern region of the state: Barra Mansa and Tres Ríos (more than 200 km from Itaocara), for processing as long-life, pasteurized milk and dairy products, which are then marketed again in Itaocara and mainly in the city of Rio de Janeiro.

CAPIL Itaocara has production of cheese, butter and pasteurized milk using 6% of the raw milk that it receives daily. In this analysis, the possibility to raise its production capacity was identified, through reducing the amount of raw milk marketed in Barra Mansa or Tres Rios. The dairy products made by CAPIL Itaocara could be marketed directly in Rio de Janeiro, and also covering all the demand in Itaocara and neighbouring municipalities.

Finally, the flow ends in the consumption of dairy products in Itaocara and Rio de Janeiro. However, it is necessary to specify that the final consumption is made throughout the region and other cities. In this thesis work, final consumption is established in the city of Rio de Janeiro, given that the physical characteristics of the product (Milk) and its transformation into dairy products do not allow a greater flow traceability.

Throughout the flow, waste is identified in each process, where the loss of dairy products in transport is the most representative - 8% of the total production, which is 9 times more than the milk consumption in Itaocara annually.

The transport process by CAPIL Itaocara is identified as a critical point in the dairy flow, where efforts should be aimed at reducing the distances travelled, transport time and investment in better cooling systems in their vehicles.

The waste food in the production process, is mainly due to the presence of diseases in animals (Mastitis), This therefore calls for technical support to family farmers.

On the other hand, the waste in consumption process is due to consumer preferences, where it is assumed that hygiene practices during the processes developed by companies such as NESTLE ® are better than those developed in regional associations as CAPIL. This also identifies an important potential for investment in infrastructure that allows improving the conditions for the dairy production in CAPIL, so that the consumption of their products is increased translating into reduced waste in final consumption.

5.2.3 Itaocara Metabolic Food Profile

The MFA of each food flow studied is presented, identifying the inputs and outputs within each metabolic process. In addition to the food flow, energy and water flows are specifically identified in the production and transport processes.

Horticultural Products Flow Itaocara							
Urban Metabolism process	**Food Flow process**	**General Index**	**Data**	**General Parameters**	**Data**	**Specific Parameters**	**Data**
Inputs	Production	Food production Itaocara (t)	**12.401**	Food Production in Itaocara	9.646	Family Farmers Production (EMATER)	9.405
						Family Farmers Production (PNAE)	241
				Surplus Production (CEASA)	2.755		
		Food production Other Municipalities (t)	**158.309,3**	Production for CEASA	**16.697,0**		
				Production for Other marketing channels	141.853,3		
		Energy Input (kWh)	**1.004.391**	Electric Energy consumption in Itaocara	1.004.391		
		Water Input (m3)	**9.296.103**	Water Consumption from " Açudes " in Itaocara	9.296.103		
		Agro -chemicals (t)	**53**				
		Land Input (ha)	**477**	Area for horticultural production in Itaocara	477		
	Marketing	Food Marketing (t)	**29.097,6**	Total Trade in CEASA from Itaocara	12.160	Trade by CEASA Itaocara	12.092
						Trade by Food Bank	68
				Total Trade in CEASA from Other Municipalities	16.697		
				Trade by PNAE	241		
	Transport	Energy Input (kWh)	**3.825.929**	Diesel consumption (gal)	**94.003**		
Outflows	Production	Food Wastage (t)	**2.480**				
		CO2 Emission (t eq)	**83**				
	Marketing	Food Wastage (t)	**5.771,3**				
	Transport	Food Wastage (t)	**3.491,7**				
		CO2 Emission (t eq)	**940**				
	Consumption	Food Consumption (t)	**29.097,6**	Food Consumption Itaocara	3.203	Consumption in Retail Market Itaocara	2.958
						Consumption PNAE	241
						Consumption Food Bank- Itaocara	4
				Consumption Food Bank-Other Municipalities	64		
				Consumption CEASA Rio de Janeiro 80%	20.664,3		
				Consumption CEASA CantaGalo 20%	5.166,1		
		Food Wastage (t)	**2.909,8**				
Total Food Wastage							**14.652,9**
Final Consumption (Production - Total Food Wastage) (t)							**14.444,7**
Theoretical Efficiency (Final Consumption/Production)*100							**50%**

Table 32:MFA Horticultural Flow

Source: Own Elaboration

Table 33:MFA Dairy Flow

Dairy Products Flow Itaocara							
Urban Metabolism process	**Food Flow process**	**General Index**	**Data**	**General Parameters**	**Data**	**Specific Parameters**	**Data**
Inputs	Production	Total Production Northwest Region (l)	**127.414.716**	Total Production Itaocara	12.067.923		
				Total Production Other Municipalitites	115.346.793		
		Energy Input (kWh)	**785.000**				
		Water Input (m3)	**389.794**				
		Land Input (ha)	**3.032**				
	Marketing	Food Marketing (l)	**122.955.201**	Food Marketing in Itaocara (l)	25.892.112	CAPIL Itaocara: Cheese /butter/Pasteur. Milk	1.553.527
						Trade by CAPIL	24.338.585
				Other Dairy Associations	97.063.088,9		
		Food Trade (l)	**118.973.641**	Barra Mansa	83.767.155,2		
				Tres Rios	35.206.485,5		
		Energy Input (kWh)	**972.000**				
	Transport	Energy Input (kWh)	**5.183.200**	Diesel consumption (gal)	127.351		
Outputs	Production	Food Wastage (l)	**4.459.515**				
		CO2 Emission (t eq)	**65**				
	Marketing	Food Wastage (l)	**2.428.033**				
		CO2 Emission (t eq)	**80**				
	Transport	Food Wastage (l)	**9.836.416**				
		CO2 Emission (t eq)	**1.341**				
	Consumption	Food Consumption (l)	**104.771.736**	Consumption in Itaocara	954.090		
				Consumption in Rio de Janeiro	103.817.646		
		Food Wastage (l)	**4.365.489**				
Total Food Wastage							**21.089.454**
Final Consumption (Production - Total Food Wastage) (l)							**106.325.262**
Theoretical Efficiency (Final Consumption/Production)*100							**83%**

Source: Own Elaboration

During the production process, the amount of land required for the food production (ha), the field of agrochemical (t), water (m^3), and energy (kWh) as inputs are highlighted as critical points. The water input is very important, mainly due to irrigation and the quantity of water required for horticultural production. The quantitative identification of water wasted as output in this process is not achieved; given that this data depends on the specific variables of each crop, type of soil, climatic and topographic characteristics, in addition to the infrastructure networks, mentioned earlier of which are almost null in rural areas.

On the other hand, energy consumption in the production process refers to the electricity consumption, which is greater in the dairy flow, due to consumption of the collection tanks located inside the farms. According to studies carried out in Latin America, the energy consumption per liter of milk produced is around 51 kWh/1000 kg of dairy products(Bartolomé et al., 2013). In Itaocara this consumption was established at 67 kWh/1000 kg by PESAGRO, indicating potentials for reduction of these consumptions; especially in optimising the capacity of the refrigeration tanks and vacuum pumping systems for milking.

A very important energy consumption occurs in the transport process, of both, horticultural and dairy products flows, due to the consumption of diesel fuel for the collection and distribution of food. It was identified that the consumption of gal-diesel/km is more efficient in the dairy flow, given the storage capacity of the tankers. The transport of horticultural food in small or low capacity trucks decreases the efficiency of this process.

The outputs, in environmental terms, are mainly Land degradation, erosion, and CO_2 emissions emitted by the electricity sector and diesel consumption.

At the end of each MFA, the theoretical efficiency determined by the FAO, 2011 for the dairy and horticultural flows is shown, where 50% was established during the whole flow of fruits and vegetables and 83% in all Dairy flow.

To compare the efficiency of food flows from the point of view of Urban Metabolism, the equation of metabolism established by Podolinsky is taken as reference, where he stateds that *"Humans have the capacity to transform a fifth of the energy obtained in the feeding into muscular work"* (J. Martínez-Alier, 2003) , which means a metabolic transformation has an efficiency of 80% (Used for functioning) and a 20% that is externalized as work. By this, the Horticultural Flow has an important potential in the transformation of their processes, mainly due to the amount of food wastage generated during production and marketing processes.

See Annex 5-6.

5.3 Challenges for Regional Food Value Chains

The challenges for regional food chain were determined after the food flows analysis. The identification of these challenges allows suggesting some recommendations for stakeholders in each of the foodsheds. The challenges were identified to minimize flows in terms of resources consumption and mainly the Food Wastage, with a focus on the livability and socio-economic welfare.

- Food Waste: It occurs at all stages of the supply chain. In the horticultural products, the greatest amount of food wastage is in the Marketing process in CEASA. This situation is mainly due to the supply excess. Here, is not a sufficient number of buyers or the purchase prices are lower than the production costs. In dairy products, the greatest food wastage is in the transportation process, where the deficiency in cooling systems does not guarantee the food safety.
- Energy consumption: It is represented in diesel fuel used to transport food. It is a significant environmental and economic challenge within food flows.
- Consumption of agrochemicals: Reducing the consumption of fertilizers and pesticides and increasing the organic production is a challenge, not just in environmental but in public health terms.
- Control in water consumption and disposal: The water consumption through " Açudes" for horticultural and dairy activities is not registered or controlled by the authorities. It does not allow the measurement of the consumption or liquid waste or control measures.
- Increase efficiency of Food Flows: Both in the horticultural and dairy products flow, there is an important opportunity to increase food production and reducing distances and travel times during the transport process at the same time.
- Land Degradation: Diversifying supply and demand of food helps to minimize the environmental challenges of the region due to the soil erosion.

5.3.1 Recommendations for Regional Food Value Chain

The recommendations of the Food Value Chain in the Northwest region can be established in environmental, economic, political or social terms, depending on the interests of the stakeholders, case in this study, they are made for the main decision makers such as the Family Farmers, the public institutions involved like EMATER, RIORURAL, CEASA, PNAE, PAA, and CAPIL.

Regarding the School Feeding Plan - PNAE; it contributes very significantly to Food Flow in Itaocara. However, it has a high potential to increase the food value chain of the region, in two ways:

First, the food requirements of the PNAE involve categories that are not produced in Itaocara, which forces the municipality to make purchases in other municipalities. Owing to this, it is possible to make a modification of the diets through the nutritionists support, which could include products such as Quiabo, which is highly produced in Itaocara and is part of the identity of the municipality and currently not within the food requirements.

Secondly, derivatives products from dairy are not part of the PNAE program, mainly because local milk production does not guarantee the quality of the products that will be delivered to students. This situation could be transformed if CAPIL makes an investment in infrastructure to improve the production, packaging, and transport conditions, in addition to diversifying its production, so that products such as yogurt could be produced and consumed in Itaocara.

Like the PNAE, the Food Bank has also a very important role in the flow of food, particularly in the minimization of food waste in the marketing process. Through the Food Bank in Itaocara, 135 tons of food are marketed every year. However, only 68 tons of these come from the Food Flow of Itaocara, and it has the largest distribution in other municipalities. A challenge for the Food Bank is identified how to improve the collection and distribution of the amount of food coming from Itaocara, in order to contribute towards the reduction of food waste and in the energy consumption for the transport process.

With regards to the interaction with other Food Flows, Itaocara presents an important potential in other food flows beside the horticultural and dairy flow. For example, the production of guava and honey, which are not currently recognized but may be larger, diversifying the production of the municipality. The livestock represents a positive source of income but has high environmental costs such as land degradation. Hence, diversification in food flows can be presented as a high-income potential at lower environmental costs.

To increase the fruits and vegetable consumption in Brazil is a great challenge for the policies focused on malnutrition, mainly given the tendencies toward obesity in the Brazilian population. The change in the diets and preferences of consumers allows a healthier diet and at the same time minimizes the waste of food in the process of consumption.

The food wastage is present in each metabolic process. Nevertheless, when there are associations or groups of organized people, it is easier to control and manage them. Hence, it is considered important to consolidate associations of products such as Quiabo, Scarlet Eggplant, Manga or Tomato that represent high productivity in Itaocara in economic and quantitative terms.

The identification and understanding of Food Flows require a flow of information that is also important because it guarantees the reliability and traceability of the data. An important challenge for the public entities is precisely to guarantee this flow of information in an accurate way.

On the other hand, CAPIL Itaocara has a capacity to receive 100,000 liters/day of raw milk but is currently receiving an average of 70,000 liters/day. This gap presents an opportunity to expand their flow by 30%, contributing to the value chain in economic and social terms for the Northwest region.

Likewise, it is important to highlight the work carried out by EMATER, where the support for the technologies transfer for family farmers allows the optimization in production processes, reducing the food wastage generated by livestock diseases or lack in agrochemicals control. There is an institutional challenge to ensure the continuity of projects such as RioRural which supports the work of EMATER.

The support to family farming is fundamental towards guaranteeing food security. A strong family farming decreases the poverty and inequality indexes. It also increases the diversity of food and the food access in far places, improving the economic income for the region. Those are only some of the multiple advantages of the contribution of family farming.

A very important challenge, not only in Brazil but in many developing countries, is the fight against corruption. At a regional and municipal level, this negative phenomenon also interferes with the development of food flows.

Finally, it is suggested to public institutions to strongly support the production and commercialization of organic products, because during the agro-ecological or sustainable processes the consumption of water, energy, and food wastage is drastically reduced.

Unfortunately, the consumption of agrochemicals in Brazil is high, in the levels of industrial food production as well as in family farming. The indiscriminate use of agrochemicals as fertilizers and pesticides is due to several factors such as the weak control for its commercialization and in some cases due to lack of knowledge about the serious environmental and social consequences, for which an important challenge is in the institutions that provide technical assistance mainly to the family farmers.

6 Conclusions

Chinese Food Market Own Photography. 2018

"No começo pensei que estivesse lutando para salvar seringueiras, depois pensei que estava lutando para salvar a Floresta Amazônica. Agora, percebo que estou lutando pela humanidade".

Chico Mendes

6.1 Evaluation of Food Flows: Urban Metabolism Approach

The evaluation of Food Flows in the Northwestern Region of Rio de Janeiro state, from the Urban Metabolism approach, allows identifying the interrelations between elements that set an urban ecosystem in terms of food security.

The evaluation of flows for dairy and horticultural products, begins with the identification of the social, economic, environmental and food security context. This allows the technical and socioeconomic processes identification. These processes lead the exchange inside and outside the food system.

The Material Flow Analysis methodology, from the urban metabolism approach, uses The Foodsheds Assessment as a tool to identify the boundaries of the system. This thesis work presents a geographic model of foodshed for dairy and horticultural products allowing to observe the boundaries of each food flow. The foodshed for dairy and horticultural products becoming a tool for private and public decision makers.

The food flows have been identified qualitatively and geographically. Hence, the food metabolic profile for Itaocara municipality is presented. It allows identifying the critical points within the food system. Food waste during the marketing process for horticultural products and in the transportation process during the food chain of dairy products are the main critical points. CEASA Market and CAPIL Association are places also identified as critical points for their important role in the whole Food Flow.

Critical points in the food system allow presenting the challenges for the regional food value chain and also recommendations from the environmental, social and economic point of view for the Northwestern region and especially for Itaocara municipality.

6.2 Research Gaps

The main gap in the research was due to the inconsistency in the production quantities for horticultural flow reported in the official database of EMATER and CEASA. It shows that the production quantities in Itaocara are greater than the foodstuffs marketed in CEASA from Itaocara. This situation could be caused by reasons, such as an error in the information flow, individual interests or lack of control among others.

Another Gap in this research is given by the limitation for measuring the real efficiency of Food Flows. As mentioned in the introductory chapter, food wastage is calculated based on the percentages established by FAO. Therefore, this thesis work incorporates a theoretical efficiency of food flows.

As these theoretical efficiencies are given for Latin America by FAO, there is no basis of comparison of the results about food flows efficiency with other studies, given that they would be similar. However, taking into account studies conducted by FAO, it was possible to identify in a qualitative and quantitative way the food wastage in each metabolic process of food flows in the Northwest region, which according to the objectives of this research were the identification and calculation of food flows under the urban metabolism approach.

A final gap is the identification of water and energy consumption in each metabolic processes. The information available during the collection data did not allow an approximation of the "real" consumption of water and energy. In the case of water consumption during the production process, the water uptake is from a source where there is generally no control such as wells, natural springs, rainwater, nearby lakes or streams. In this thesis, the water and energy consumption is hereby determined from the quantities required for each type of crop, according to the literature review.

6.3 Future Perspectives

The studies of urban metabolism are being increasingly recognized and consolidated as a fundamental tool in the analysis s of energy and matter flows, so that they present a "Bird Eyes" for decision-makers and stakeholders in cities.

The evaluation of Food Flow through the Urban Metabolism approach allows a look into the complexity of the processes that set it up. The identification of the inputs and outputs of a food system is fundamental to the policies establishment aimed at guaranteeing the food security.

However, it is possible to consider that the limitations and gaps in this type of evaluation, make use of assumptions for the inputs and outputs calculation. Hence, the demand for necessary resources should be considered in future research with the purpose of calculating the real wastage, land degradation, or the environmental degradation due to water and energy consumption and CO_2 emissions in Food Flows.

In a study of Urban Metabolism focused on the Food Flow, the better presentation of results would be in kilocalories units. In this units, it would be possible to make the traceability from the number of kilocalories that are necessary for the food production, the number of kilocalories of the foodstuff and likewise to compare this information with the kilocalories required in a healthy diet and in the final kilocalories consumption.

However, this analysis depends on each research objectives, and in the case of this study, it was considered that the interpretation of the final results expressed in terms of kilocalories could be confusing and hinder the decision making of the stakeholders.

Finally, the analysis of the Urban Metabolism model in Food Flows should be focused on the social, economic and environmental welfare, which goes beyond the reduction of inputs and outputs in the metabolic process. Likewise, bearing in mind that before the identification of critical points, the improvement of the system efficiency or the identification of challenges in any matter and energy flow, it is necessary to first understand how the matter and energy flow through the system.

BIBLIOGRAPHY

Albeiro. (2014). Utilização de energia na agricultura. Retrieved July 20, 2018, from http://www.diadecampo.com.br/zpublisher/materias/Materia.asp?id=23369&secao=Colunas e Artigos

Ángel Martínez, M., Martín Górriz, B., & Martínez Álvarez, V. (2012). Análisis enérgetico de los principales cultivos de la región de Murcia – España. Retrieved from http://repositorio.upct.es/bitstream/handle/10317/3587/pfc5253.pdf;sequence=1

Arrúe, J. L., Fuentes, J. Á., & Martinez, C. (2013). La eficiencia energética en la agricultura de conservación frente a la agricultura tradicional. Retrieved from http://www.agriculturadeconservacion.org/

Bai, X. (2016). Eight energy and material flow characteristics of urban ecosystems. Ambio, 45(7), 819–830. https://doi.org/10.1007/s13280-016-0785-6

Barrera-Bassols, N., & Toledo, V. M. (2008). La memoria biocultural.

Bartolomé, D. J., Posado, R., Bodas, R., Tabernero de Paz, M. J., García, J. J., & Olmedo, S. (2013). Caracterización del consumo eléctrico en las granjas de vacuno lechero de Castilla y León. Archivos de Zootecnia, 62(239), 447–455. https://doi.org/10.4321/S0004-05922013000300013

Bastos, Julia; Napoleao, P. (2010). O Estado do Ambiente Indicadores Ambientais do Rio de Janeiro 2010.

Benavides, L. E. (2017). Advancing sustainability in Latin America cities: a study case on the urban metabolism in San Luis Potosí, México.

Benedictus, L. (2014). Sick cities: why urban living can be bad for your mental health | Cities | The Guardian. Retrieved from https://www.theguardian.com/cities/2014/feb/25/city-stress-mental-health-rural-kind

Blay-Palmer, A. (2009). The Canadian Pioneer: The Genesis of Urban Food Policy in Toronto, 14(4). https://doi.org/10.1080/13563471003642837

Blum-Evitts, S. (2009). Designing a Foodshed Assessment Model: Guidance for Local and Regional Planners in Understanding Local Farm Capacity in Comparison to Local Food Needs. Retrieved from https://scholarworks.umass.edu/theses

Bodini, A., Bondavalli, C., & Allesina, S. (2012). Cities as ecosystems: Growth , development and implications for sustainability. Ecological Modelling, 245, 185–198. https://doi.org/10.1016/j.ecolmodel.2012.02.022

Brinkley, C. (2013). Avenues into Food Planning: A Review of Scholarly Food System Research. International Planning Studies, 18(2), 243–266. https://doi.org/10.1080/13563475.2013.774150

Brunner, P. H. (2002). Beyond Materials Flow Analysis. Journal of Industrial Ecology, 6(1), 8–10. https://doi.org/10.1162/108819802320971597

Brunner, P., & Rechberger, H. (2005). Practical Handbook of Material Flow Analysis. Retrieved from https://thecitywasteproject.files.wordpress.com/2013/03/practical_handbook-of-material-flow-analysis.pdf

Bucher, T., Müller, B., & Siegrist, M. (2015). What is healthy food? Objective nutrient profile scores and subjective lay evaluations in comparison. Appetite. Retrieved from https://ac.els-cdn.com

Caminos y Puentes. (2004). Tabla de rendimientos de combustible para vehículos, maquinaria y equipo de conservación. Retrieved from http://www.capufe.gob.mx/site/normateca/normas/77_Bases_para_la_Administracion_del_Parque_de_Maquinaria_a_cargo_de_CAPUFE_dic_05/Anexo05.pdf

Capel, H. (1975). La definicion de lo urbano. Retrieved from http://www.ub.edu/geocrit/sv-33.htm

Capello, R., Nijkamp, P., & Pepping, G. (1999). Sustainable Cities and Energy Polices.

CEASA. (2018). Personal Interview to CEASA - ITAOCARA Director Plant.

Centro de Mecanización Agropecuaria, Instituto Superior de Ciencias Agropecuarias de la Habana., J., López Seijas, T., & Cid Lazo, G. (2014). Revista ciencias técnicas agropecuarias. Revista Ciencias Técnicas Agropecuarias (Vol. 23). Centro de Mecanización Agropecuaria, Instituto Superior de Ciencias Agropecuarias de la Habana. Retrieved from http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S2071-00542014000400004

Christen, A., Coops, N., & Van Der Laan, M. (2010). A LiDAR-Based Urban Metabolism Approach to Neighbourhood Scale Energy and Carbon Emissions Modelling. Retrieved from https://www.researchgate.net/profile/Andreas_Christen/publication/234841805_A_LiDAR-Based_Urban_Metabolism_Approach_to_Neighbourhood_Scale_Energy_and_Carbon_Emissions_Modelling/links/02bfe510242094dfb2000000/A-LiDAR-Based-Urban-Metabolism-Approach-to-Neig

Commission for Environmental Cooperation. (2018). Comisión para la Cooperación Ambiental | Tres países unidos en la protección del medio ambiente que compartimos. Retrieved July 3, 2018, from http://www.cec.org/es

Comunidad de los estados Latinoamericanos y Caribeños - CELAC. (2018). Plataforma de seguridad alimentaria y nutricional. Retrieved July 3, 2018, from https://plataformacelac.org/ley/68

CONAB. (2016). Programa de Aquisião de Alimentos - Resultado das Ações 2015.

Costa, A. (2008). General Aspects of Sustainable Urban Development. 365–380.

Day, John W; Hall, C. (2016). America's Most Sustainable Cities and Regions.

DeWeerdt, S. (2011). Is Local Food Better? Retrieved June 29, 2018, from http://www.worldwatch.org/node/6064

Díaz Álvarez, C. (2014). Urban metabolism: a tool for the sustainability of cities. Interdisciplina, 2(2), 51–70.

Dimitri, C., Oberholtzer, L., & Pressman, A. (2016). Urban agriculture: connecting producers with consumers. British Food Journal, 118(3), 603–617. https://doi.org/10.1108/BFJ-06-2015-0200

East, S. (2016). How to stop city life from stressing you out- CNN. Retrieved from https://edition.cnn.com/2016/10/11/health/reducing-stress-in-the-city-can-improve-mental-health/index.html

El-Abbadi, N., Peters, C., Griffin, T., Nelson, M., & Jacques, P. (2017). Development of a dietary environmental index to assess nutritional quality versus environmental effect of foods and dietary patterns. The Lancet, 389, S6. https://doi.org/10.1016/S0140-6736(17)31118-2

EMATER-RIO. (2017). Relatório de Atividades 2017 EMATER - RIO. Retrieved from http://www.emater.rj.gov.br/pdf/Relatorio_de_atividades2017.pdf

Emater-Rio, & Pesagro-Rio. (2015). Relatório de perdas no setor agropecuário no estado do Rio de Janeiro, 61.

EMBRAPA. (2014). Mapeamento pedólogico e interpretações úteis ou Planejamento ambiental do Rio de Janeiro.

Eurostat. (2001). Economy-wide material flow accounts and derived indicators. Fuel. https://doi.org/10.1016/j.marpolbul.2013.07.028

Feagan, R. (2007). The place of food: mapping out the 'local' in local food systems. Progress in Human Geography, 31(1), 23–42. https://doi.org/10.1177/0309132507073527

Figueroa Pedraza, D. (2003). Seguridad Alimentaria y Nutricional en Brasil. Retrieved from http://respyn.uanl.mx/index.php/respyn/article/viewFile/133/115

Fischer-Kowalski, M. (2011). Analyzing sustainability transitions as a shift between socio-metabolic regimes. Environmental Innovation and Societal Transitions, 1(1), 152–159. https://doi.org/10.1016/j.eist.2011.04.004

Flores Velázquez, J. (2015). Riego en cultivos de alto rendimiento | Hortalizas. Retrieved July 25, 2018, from https://www.hortalizas.com/cultivos/riego-en-cultivos-de-alto-rendimiento-a-campo-abierto-y-en-condiciones-protegidas/

FNDE. (2015). Aquisição de Produtos da Agricultura Familiar para a alimentação escolar. Retrieved from http://www.fnde.gov.br/

FNDE. (2016). Programa Nacional de Alimentação Escolar. Retrieved from http://www.fnde.gov.br/

FAO - Food and Agriculture Organization. (1996). World Food Summit: Rome Declaration on World Food Security and World Food Summit Plan of Action. World Food Summit, 1–32. https://doi.org/10.2307/2137827

FAO - Food and Agriculture Organization. (2011). Global food losses and food waste: extent, causes and prevention. Save Food! (May), 38. https://doi.org/10.1098/rstb.2010.0126

FAO - Food and Agriculture Organization of the United Nations. (2013). Food Wastage Footprint Impacts on natural resources. Technical Report, 249.

FAO - Food and Agriculture Organization. (2012). Respuesta del rendimiento de los cultivos al agua. Retrieved from www.fao.org

FAO - Food and Agriculture Organization. (2016). FAOSTAT. Retrieved July 16, 2018, from http://www.fao.org/faostat/en/#country/21

FAO - Food and Agriculture Organization of the United Nations. (2015). Estimación de emisiones de gases de efecto invernadero en la agricultura. Retrieved from http://www.fao.org/3/a-i4260s.pdf

FAO - Food and Agriculture Organization of the United Nations. (2017). El estado de la seguridad alimentaria y la nutrición en el mundo 2017. Retrieved from http://www.fao.org/3/a-I7695s.pdf

FAO - Food and Agriculture Organization of the United Nations, & Platform for Agrobiodiversity Research. (2011). Biodiversity for Food and Agriculture - Contributing to food security and sustainability in a changing world. Retrieved from http://www.fao.org/3/a-i1980e.pdf

Fradkin, E. (2015). Can Lopez Island Feed Itself? A foodshed assessment of Lopez Island, Washington. Retrieved from http://www.lopezclt.org/wp-content/uploads/Lopez-Island-Foodshed-Assessment.pdf

Francis, C. A., & Wezel, A. (2015). Agroecology and Agricultural Change. International Encyclopedia of the Social & Behavioral Sciences, 484–487. https://doi.org/10.1016/B978-0-08-097086-8.91026-2

Fuente Carrasco, M. (2004). La economía ecológica: Un paradigma para abordar la sustentabilidad. América Latina: Los Desafíos Del Pensamiento Crítico, 126(56). Retrieved from http://www.redalyc.org/articulo.oa?id=59505605

Garcia Serna, M., Morales Pinzón, T., & Guerrero, J. (2014). Análisis de flujos de agua en áreas metropolitanas desde la perspectiva del metabolismo urbano. Luna Azul.

Giampietro, M., Mayumi, K., & Alevgiil H, S. (2012). The Metabolic Pattern of Societies.

Giampietro, M., Mayumi, K., & Ramos-Martin, J. (2008). Multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM): Theoretical concepts and basic rationale. https://doi.org/10.1016/j.energy.2008.07.020

Girardet, H. (1996). The Gaia atlas of cities: New directions for sustainable urban living. Gaia.

González de Molina, M., & Toledo, V. M. (2014). The social metabolism: A socio-ecological Theory of Historical change.

Gragson, T., & Grove, M. (2006). Social Science in the Context of the Long Term Ecological Research Program. Society and Natural Resources, 19(2), 93–100. https://doi.org/10.1080/08941920500394410

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., & Briggs, J. M. (2008). Global Change and the Ecology of Cities.

Guerrero, E. M., & Guiñirgo, F. (2008). Indicador espacial del metabolismo urbano . Huella Ecológica, 9, 31–44.

Haberl, H. (2015). Energy Flow Analysis. In International Encyclopedia of the Social & Behavioral Sciences (pp. 626–632). Elsevier. https://doi.org/10.1016/B978-0-08-097086-8.91059-6

Haberl, H., Fischer-Kowalski, M., Krausmann, F., Martinez-Alier, J., & Winiwarter, V. (2011). A socio-metabolic transition towards sustainability? Challenges for another Great Transformation. Sustainable Development, 19(1), 1–14. https://doi.org/10.1002/sd.410

Haberl, H., Fischer-Kowalski, M., Krausmann, F., Weisz, H., & Winiwarter, V. (2004). Progress towards sustainability? What the conceptual framework of material and energy flow accounting (MEFA) can offer. Land Use Policy, 21(3), 199–213. https://doi.org/10.1016/j.landusepol.2003.10.013

Halweil, B. (2002). Home Grown: The case for local food in a global market. Retrieved from http://www.worldwatch.org/system/files/EWP163.pdf

Hedden, W. P. (1929). How great cities are fed. Retrieved June 28, 2018, from https://openlibrary.org/books/OL6736131M/How_great_cities_are_fed

Hernandez, C. (2017). El suelo: el gran desconocido del cambio climático |. Retrieved May 23, 2018, from https://ctxt.es/es/20170705/Firmas/13768/clima-cambio-climatico-suelo-contaminacion.htm

IBGE. (2004). Indicadores de desenvolvimento sustentável - Brasil 2004 Dimensão ambiental. Retrieved from https://ww2.ibge.gov.br/home/geociencias/recursosnaturais/ids/terra.pdf

IBGE. (2006). Censo Agropecuário Brasil 2006, 2009.

IBGE. (2010). Pesquisa de Orçamentos Familiares 2008-2009. Retrieved from https://biblioteca.ibge.gov.br/visualizacao/livros/liv47310.pdf

IBGE. (2013). Pesquisa Nacional de Saúde. Retrieved from ftp://ftp.ibge.gov.br/PNS/2013/pns2013.pdf

IBGE. (2014). Tabela 770: Quantidade de fertilizantes entregue ao consumidor final e Utilização de fertilizantes por unidade de área por tipo de nutriente. Retrieved July 21, 2018, from https://sidra.ibge.gov.br/tabela/770#resultado

IBGE. (2016). Instituto Brasileiro de Geografia e Estatística - Itaocara. Retrieved from https://www.ibge.gov.br/busca.html?searchword=itaocara&searchphrase=all

IBGE. (2018). IBGE: Instituto Brasileiro de Geografia e Estatística. Retrieved July 3, 2018, from https://www.ibge.gov.br/institucional/o-ibge.html

INTECRAL-RioRural. (2018). Rio Rural – INTECRAL. Retrieved July 8, 2018, from http://intecral-project.web.th-koeln.de/wordpress/?page_id=103

International Energy Agency. (2017). World Energy Outlook 2017. Retrieved from http://www.iea.org/media/weowebsite/2017/Chap1_WEO2017.pdf

Jackson, M. C. (2003). Systems Thinking: Creative Holism for Managers. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.476.2858&rep=rep1&type=pdf

Kennedy, C., Baker, L., & Brattebø, H. (2014). Analyzing a city' s metabolism.

Kennedy, C., Cuddihy, J., & Engel-yan, J. (2007). The changing metabolism of Cities, 11(2).

Kennedy, C., Pincetl, S., & Bunje, P. (2010). The study of urban metabolism and its applications to urban planning and design. Environmental Pollution. https://doi.org/10.1016/j.envpol.2010.10.022

King, T., Cole, M., Farber, J. M., Eisenbrand, G., Zabaras, D., Fox, E. M., & Hill, J. P. (2017). Food safety for food security: Relationship between global megatrends and developments in food safety. Trends in Food Science and Technology, 68, 160–175. https://doi.org/10.1016/j.tifs.2017.08.014

Lea, E., Worsley, A., & Crawford, D. (2005). Food industry awareness of consumers' plant food beliefs. British Food Journal, 107(8), 556–571. https://doi.org/10.1108/00070700510610977

Lederbogen, F., Kirsch, P., Haddad, L., Streit, F., Tost, H., Schuch, P., Meyer-Lindenberg, A. (2011). City living and urban upbringing affect neural social stress processing in humans. Nature, 474(7352), 498–501. https://doi.org/10.1038/nature10190

Ludwig, R., Mauser, W., Niemeyer, S., Colgan, A., Stolz, R., & Escher-vetter, H. (2003). Web-based modelling of energy , water and matter fluxes to support decision making in mesoscale catchments — the integrative perspective of GLOWA-Danube, 28, 621–634. https://doi.org/10.1016/S1474-7065(03)00108-6

Lupton, R. C., & Allwood, J. M. (2017). Hybrid Sankey diagrams: Visual analysis of multidimensional data for understanding resource use. https://doi.org/10.1016/j.resconrec.2017.05.002

Malik, F. F. (2010). Management: the essence of the craft. Campus Verlag. Retrieved from https://books.google.de/books/about/Management.html?id=Lb1VPgAACAAJ&redir_esc=y

Manzanares, P. (1997). Introducción al Cálculo del Balance energético de la Producción de Biomasa. Retrieved from http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/38/106/38106923.pdf

Margalef, R. (2002). Teoría de los sistemas ecológicos. Retrieved from http://web.uaemex.mx/fapur/docs/cediat/CA_agosto_2010.pdf

Martínez-Alier, J. (2003). Ecología industrial y metabolismo socioeconómico: concepto y evolución histórica. Retrieved from http://www.minetad.gob.es/Publicaciones/Publicacionesperiodicas/EconomiaIndustrial/RevistaEconomiaIndustrial/352/Economia02.pdf

Martínez-Alier, J., & Muradian, R. (2015). Taking stock: the keystones of ecological economics. Handbook of Ecological Economics, 1–25. https://doi.org/10.4337/9781783471416

Martinez, S., Hand, M., Da Pra, M., Pollack, S., Ralston, K., Smith, T., … Newman, C. (2010). Local Food Systems Concepts, Impacts, and Issues. Retrieved from https://static1.squarespace.com/static/51b0ce25e4b0e8d244de368b/t/51ffd7afe4b0fbd6b7edd81c/1375721391675/Local+Food+Systems-+Concepts%2C+Impacts%2C+and+Issues.pdf

Maye, D. (2017). "Smart food city": Conceptual relations between smart city planning, urban food systems and innovation theory. https://doi.org/10.1016/j.ccs.2017.12.001

Meadows, D. H. (2009). Thinking in Systems. Retrieved from http://wtf.tw/ref/meadows.pdf

Ministério da Saúde. (2016). Vigitel Brasil 2016: Hábitos dos brasileiros impactam no crescimento da obesidade e aumenta prevalência de diabetes e hipertensão. Retrieved from http://portalarquivos.saude.gov.br/images/pdf/2017/maio/12/Lancamento-resultados-2016.pdf

Ministério de Minas y Energía Brasil. (2016). Brazilian Energy Balance. Retrieved from https://ben.epe.gov.br/downloads/Relatorio_Final_BEN_2017.pdf

Ministério do Desenvolvimento Social e Agrário do Brasil. (2017). Plano Nacional de Seguranca Alimentar e Nutricional. Retrieved from http://www.mds.gov.br/webarquivos/arquivo/seguranca_alimentar/caisan/plansan_2016_19.pdf

Minx, J., Creutzig, F., Medinger, V., Ziegler, T., Owen, A., & Baiocchi, G. (2011). Developing a Pragmatic Approach to Assess Urban Metabolism in Europe - A report to the european environment agency. CLIMATECON Climatecon Working Paper Series . Retrieved from http://ideas.climatecon.tu-berlin.de/documents/wpaper/CLIMATECON-2011-01.pdf

Moffatt, S. (2010). Ciudades Eco.

Murphy, P. (2008). Plan C: Community Survival Strategies for Peak Oil and Climate Change. Retrieved June 29, 2018, from https://books.google.de/books

Neth, H., & Gigerenzer, G. (2015). Heuristics: Tools for an Uncertain World. https://doi.org/10.1002/9781118900772.etrds0394

Newman, P. W. G. (1999). Sustainability and cities: Extending the metabolism model, 44(September 1998), 219–226.

Newspaper Extra. (2016). Único prefeito do PSOL no Rio é condenado por abuso de poder. Retrieved July 12, 2018, from https://extra.globo.com/noticias

O 'hara, J. K., & Pirog, R. (2013). Economic impacts of local food systems: Future research priorities. Journal of Agriculture, Food Systems, and Community Development, 3(34), 35–42. https://doi.org/10.5304/jafscd.2013.034.003

Odum, E. (1971). Ecología. Journal of Chemical Information and Modeling (Vol. 53). https://doi.org/10.1017/CBO9781107415324.004

Odum, H. T. (1996). Environmental Accounting: Emergy and Environmental Decision Making.

Organización de las Naciones Unidas para la Alimentación y la Agricultura & Organización Panamericana de la Salud. (2017). Panorama de la seguridad alimentaria y nutricional en América Latina y el Caribe. Retrieved from http://www.fao.org/3/a-i7914s.pdf

Peters, C. J., Bills, N. L., Wilkins, J. L., & Fick, G. W. (2009). Foodshed analysis and its relevance to sustainability. Renewable Agriculture and Food Systems, 24(01), 1–7. https://doi.org/10.1017/S1742170508002433

Peters, C. J., Wilkins, J. L., & Fick, G. W. (2008). Land and Diet: What' s the most land efficient diet for New York State? ISSUE NUMBER, 19. Retrieved from http://senecacountycce.org/resources/land-diet-what-s-the-most-land-efficient-diet-for-new-york-state

Pickett, S. T. A., Burch, W. R., Dalton, S. E., Foresman, T. W., Grove, J. M., & Rowntree, R. (1997). A conceptual framework for the study of human ecosystems in urban areas. Retrieved from https://www.fs.fed.us/nrs/pubs/jrnl/1997/ne_1997_pickett_001.pdf

Pincetl, S., Bunje, P., & Holmes, T. (2012). An expanded urban metabolism method: Toward a systems approach for assessing urban energy processes and causes. Landscape and Urban Planning, 107(3), 193–202. https://doi.org/10.1016/J.LANDURBPLAN.2012.06.006

Pirog, R. S., & Mccann, N. W. (2009). Is Local Food More Expensive? A Consumer Price Perspective on Local and Non-local Foods Purchased in Iowa. Retrieved from http://lib.dr.iastate.edu/leopold_pubspapers

Prefeitura Municipal Itaocara. (2012). Plano Municipal de Saneamento Básico - Itaocara.

Ramos-Martin, J. (2006). Complex systems and exosomatic energy metabolism of human societies. Retrieved from https://www.researchgate.net/publication/277206570

Randle, J. M., & Stroink, M. L. (2018). The Development and Initial Validation of the Paradigm of Systems Thinking. Systems Research and Behavioral Science, (April). https://doi.org/10.1002/sres.2508

Reina, J. D. (2013). Metabolismo Social: Hacia la sustentabilidad de las transiciones socio ecológicas urbanas, 155. Retrieved from http://www.bdigital.unal.edu.co/12514/

Reynolds, B. (2009). Feeding a World City: The London Food Strategy. International Planning Studies, 14(4), 417–424. https://doi.org/10.1080/13563471003642910

Rocha, C., & Lessa, I. (2009). Urban Governance for Food Security: The Alternative Food System in Belo Horizonte, Brazil. International Planning Studies, 14(4), 389–400. https://doi.org/10.1080/13563471003642787

Rosado, L., & Kalmykova, Y. (2016). Urban metabolism profiles. An empirical analysis of the material fl ow characteristics of three metropolitan areas in Sweden, 126, 206–217. https://doi.org/10.1016/j.jclepro.2016.02.139

Satterthwaite, D., Satterthwaite, D., Haughton, G., Budds, J., & Dodman, D. (2008). Cities ' contribution to global warming : notes on the allocation of greenhouse gas emissions.539–549. https://doi.org/10.1177/0956247808096127

Schmidt, A. (1976). El concepto de Naturaleza en Marx.

Secretaria de Estado do Ambiente RJ. (2015). Plano Municipal de Conservação e Recuperação da Mata Atlântica da Itaocara. Retrieved from http://www.inea.rj.gov.br/cs/groups/public/@inter_vpres_geiat/documents/document/zwew/mtq4/~edisp/inea0148021.pdf

Shaub, G., & Turek, T. (2011). Energy Flows, Material Cycles and Global Development.

Soto, D., Infante-amate, J., Guzmán, G. I., Cid, A., Aguilera, E., García, R., … Molina, D. (2016). The social metabolism of biomass in Spain , 1900 – 2008 : From food to feed-oriented changes in the agro-ecosystems. Ecological Economics, 128, 130–138. https://doi.org/10.1016/j.ecolecon.2016.04.017

Stuart Chapin, F., Matson, P. A., & Vitousek, P. M. (2012). Principles of terrestrial ecosystem ecology. 1–529. https://doi.org/10.1007/978-1-4419-9504-9

Subsecretaria de Desenvolvimento Econômico RJ. (2018). Indicadores e dados econômicos. Retrieved July 8, 2018, from http://www.rj.gov.br/web/sedeis/exibeconteudo?article-id=317302

The International Standards Organisation ISO (2006). International Standard Assessment - ISO 14044 Requirements and guidelines. The International Journal of Life Cycle Assessment, 2006(7), 652–668. https://doi.org/10.1007/s11367-011-0297-3

Tichenor, N. E., Peters, C. J., Norris, G. A., Thoma, G., & Griffin, T. S. (2017). Life cycle environmental consequences of grass-fed and dairy beef production systems in the Northeastern United States. Journal of Cleaner Production, 142, 1619–1628. https://doi.org/10.1016/j.jclepro.2016.11.138

Tippins, M. J., Rassuli, K. M., & Hollander, S. C. (2002). An assessment of direct farm-to-table food marketing in the USA. International Journal of Retail & Distribution Management, 30(7), 343–353. https://doi.org/10.1108/09590550210433329

Toledo, V. M. (2008). Metabolismos rurales: Hacia una teoría económico-ecológica de la apropiación de la naturaleza, 7, 1–26.

Toledo, V. M. (2013). El metabolismo social: una nueva teoría socioecológica. Relaciones (Zamora), 34(136), 41–71. Retrieved from http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0185-39292013000400004

United Nations (2016). The World's Cities in 2016. Retrieved from http://www.un.org/en/development/desa/population/publications/pdf/urbanization/the_worlds_cities_in_2016_data_booklet.pdf

United Nations Global Compact Office. (2008). Food Sustainability: A Guide to Private Sector action. Retrieved from http://www.un.org/millenniumgoals/2008highlevel/pdf/background/foodsus_guide_EMBARGOED.pdf

Universidad de la Republica. (2015). Necesidades hídricas de Cultivos intensivos 2015. Retrieved from http://www.fagro.edu.uy/hidrologia/riego/Necesidades hidricas de Cultivos intensivos2015.pdf

Universidad Nacional de Entre Ríos. (2010). Balance de energía en cultivos hortícolas a campo en Rosario,Argentina. Ciencia, docencia y tecnología. Retrieved from http://www.scielo.org.ar/scielo.php?script=sci_arttext&pid=S1851-17162010000200007

Universidade Federal Viçosa. (2008). Novo Manual de Olericultura: Agrotecnologia moderna na produção e comercialização de hortaliças.

Walter A. Pengue. (2002). Comercio desigual y deuda ecológica, Lo que el Norte le debe al Sur. Retrieved from http://www.rcade.org/comisiones/decol/walter.pdf

WCED. (1987). Our Common Future: Report of the World Commission on Environment and Development. Retrieved from http://www.un-documents.net/our-common-future.pdf

Wiedenhofer, D., Rovenskaya, E., Haas, W., Krausmann, F., Pallua, I., & Fischer-Kowalski, M. (2013). Is there a 1970s syndrome? Analyzing structural breaks in the metabolism of industrial economies. Energy Procedia, 40, 182–191. https://doi.org/10.1016/j.egypro.2013.08.022

World Bank. (2010). Cities and climate change: An urgent agenda. Retrieved from http://siteresources.worldbank.org/INTUWM/Resources/340232-1205330656272/CitiesandClimateChange.pdf

Zhang, Y. (2013). Urban metabolism: A review of research methodologies. Environmental Pollution, 178, 463–473. https://doi.org/10.1016/j.envpol.2013.03.052

Zhang, Y., Yang, Z., & Li, W. (2006). Analyses of urban ecosystem based on information entropy, 7, 1–12. https://doi.org/10.1016/j.ecolmodel.2006.02.032

Zhang, Y., Yang, Z., & Yu, X. (2008). Measurement and evaluation of interactions in complex urban ecosystem. Ecological Modelling, 196(1–2), 77–89. https://doi.org/10.1016/j.ecolmodel.2006.02.001

ANNEX

Annex 1: Data accuracy

DATA REQUIREMENT	Case Study general information and context			Food production methods			Food production quantity			Nutritional food power/ Quality food			Imported / Exported Food			Food Stocks			Food transport and distribution			Energy consumption on food flows			Water Consumption on food flows			Food wastage			Food consumption patterns and diet			Geographical distribution of food flows			Land Use		
	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable
IBGE - Instituto Brasilero de geografia e estadistica (Brazilian Institute of Geography and Statistics)																																							
SEAPEC -Secretaria de estado de agricultura, pecuaria, pesca y abastacimiento (Secretary of State for Agriculture, Livestock, Fisheries and Supply)																																							
EMATER - Empresa é responsável pela assistência técnica e extensão rural no Estado do Rio de Janeiro (Office responsible for technical assistance and rural extension not State of Rio de Janeiro)																																							
PESAGRO - Pesquisa e desenvolvimento tecnologico no segmento agropecuario no estado de Rio de Janeiro (Research and technological development on agricultural segment not Rio de Janeiro state)																																							
EMBRAPA -Empresa Brasilera de pesquisa agropecuaria (Brazilian agricultural research office)																																							
Cadastro ambiental rural (Rural environmental register)																																							
CEASA - centrais de abastecimento do Rio de Janeiro (Central supply offices of Rio de Janeiro state)																																							

Fully meets the criteria | No certainty | No certainty

DATA REQUIREMENT	Case Study general information and context			Food production methods			Food production quantity			Nutritional food power/ Quality food			Imported / Exported Food			Food Stocks			Food transport and distribution			Energy consumption on food flows			Water Consumption on food flows			Food wastage			Food consumption patterns and diet			Geographical distribution of food flows			Land Use		
	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable	Accessible	Available	Reliable
Secreatria de saúde de Rio de Janiero - Health secretary of Rio de Janeiro state																																							
INEA - Instituto estadual de Ambiente (State Environmental Institute)																																							
CEDAE - Companhia Estadual de Águas e Esgotos (State Water and Sewage Company)																																							
RIORURAL Project - Word Bank																																							

Fully meets the criteria | No certainty | No certainty

Annex 2: Interview Format

Avaliação do fluxo de alimentos: metabolismo urbano Itaocara

Identificação do fluxo:

❑ Produção ❑ Transporte ❑ Distribuição ❑ Marketing ❑ Consumo ❑ Desperdicio

Nome: ____ Microbacia: ______________________

Área: ____________________ Organização:_________________ Endereço:_________________________

Produto: _______________________________________ Data:___________________________

Descrição da atividade:

Tempo:

Pessoal:

Processo (aquisição, armazenamento, transporte, venda):

Programa:

Coleta de dados:

Quantidade de entrada

Quantidade de saída:

Quantidade desperdiçada:

Interconexões e relacionamentos

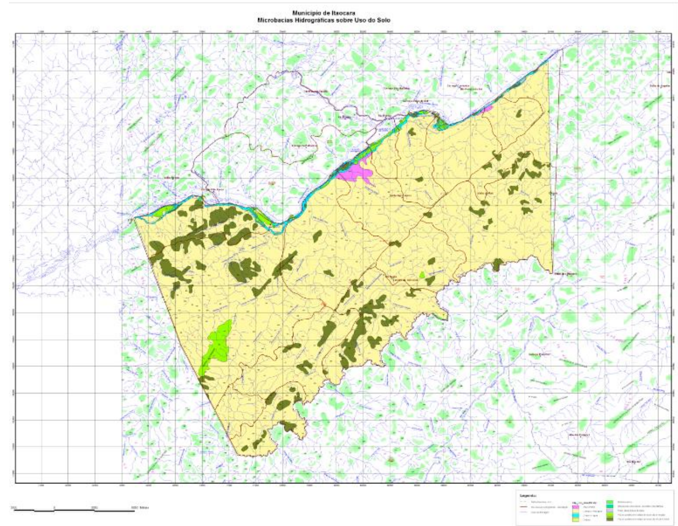
Com quais entidades / pessoas / instituições são seus relacionamentos?

❑ Productores ❑ Atacadista ❑ Cooperativa ❑ Consumidores ❑ Instituições

❑ Otra

Interconexões geograficas

ITAOCARA



Descrição e distâncias:

Identificação de consumos

Consumo de energia (quantidade e tipo):

- Uso de Combustíveis
- Uso de Máquinas
- Uso de Veículos
- Equipamento de refrigeração

Consumo de agua:

- Sistemas de irrigação
- sistema de captação e eliminação

Geração de emissões e residuos:

- Aromas
- Partículas
- Uso de fertilizantes

Contato e Visita

Annex 3: Photography Records


RIO
RURAL

Annex 4: Study Case Selection - Data

MUNICIPALITY	PRODUCTION CATEGORY:								
	MP: Meat Production			CP: Crop Production			MP: Milk Production		
	Diversity Production	No. of Farmers	Production Quantity (Tons)	Diversity Production	No. of Farmers	Production Quantity (Tons)	No. of Farmers	%	Production Quantity (L)
Aperibé	1	1	12	1	2	40	266	6%	3188353
Bom Jesus do Itabapoana	1	1	0,5	4	18	755	506	10%	17.119.371
Cambuci	2	9	160,2	2	115	2456	650	13%	13.962.000
Italva	0	0	0	3	56	836	244	5%	8.673.147
Itaocara	2	205	1790	7	669	10060,5	778	16%	12.067.923
Itaperuna	5	309	315,6	2	45	1895	602	12%	21.642.954
Leje do Muriaé	0	0	0	0	0	0	177	4%	5.803.960
Miracema	0	0	0	2	14	258,3	277	6%	5.902.914
Natividade	1	7	180*	0	0	0	251	5%	8.759.204
Porciúncula	1	1	525	4	941	12743	178	4%	5.869.345
San José de Ubá	0	0	0	3	452	23710	335	7%	5.166.007
San Antonio de Padua	1	202	2916	0	0	0	423	9%	14.314.320
Varre-Sai	1	1	135	2	550	1570,5	147	3%	4.945.218

Source. EMATER 2016,2017

Annex 5: MFA Balance for Dairy Flow

2016	L	Inputs	Outputs
Production	**127.414.716,0**		
Total Production Northwest Region	**127.414.716,0**		
Total Production Itaocara	12.067.923,0	12.067.923,0	
Total Production Other Municipalitites	115.346.793,0	115.346.793,0	
Waste of Milk	**4.459.515,1**		4.459.515,1
Marketing	**122.955.200,9**		
CAPIL Itaocara	**25.892.112,0**		
CAPIL Itaocara: Cheese and butter production	1.553.526,7		1.553.526,7
Other Dairy Associations	97.063.088,9		
Total Marketing	**121.401.674,2**		
Barra Mansa long-life milk production	83.767.155,2		
NESTLE - Tres Rios	35.206.485,5		
Waste of Milk Marketing	**2.428.033,5**		2.428.033,5
Transport	**118.973.640,7**		
Waste of Milk Transport	**9.836.416,1**		9.836.416,1
Consumption	**109.137.224,7**		
Rio de Janeiro City	103.817.645,7		103.817.645,7
Itaocara	954.090,0		954.090,0
Waste of Milk Consumption	**4.365.489,0**		4.365.489,0
Total Milk Waste	**21.089.454**		
Real Milk Consumption	**104.771.735,7**		
BALANCE		**127.414.716,0**	**127.414.716,0**

Annex 6: MFA Balance for Horticultural Flow

2017	T	Inputs	Outputs
Production	**12.400,6**		
Food Production Itaocara	**12.400,6**		
Family Farmers Production (EMATER)	9.404,6	9.404,6	
Family Farmers Production (PNAE)	241,0	241,0	
Surplus Production (CEASA)	2.755,0	2.755,0	
Food Waste	**2.480,1**		2.480,1
Production Other Municipalities	158.309,3		
Marketing CEASA	**28.856,6**		
Trade by CEASA from Itaocara	12.159,6		
Trade by PNAE	241,0		41,0
Trade by Food Bank (CEASA Itaocara)	**68,0**		
Food Waste	**5.771,3**		5.771,3
Trade by CEASA from Other Municipalities	**16.697,0**	16.697,0	
Trade by Other Marketing chanels from Other municipalities	141.853,3		
Transport	**29.097,6**		3.491,7
Food Waste	**3.491,7**		
Consumption	**29.097,6**		
Consumption in Retail Market Itaocara	2.958,2		
Consumption PNAE- School	241,0		
Consumption FB- Philant. Inst. Itaocara	**4,0**		
Consumption FB- Philant. Inst. Other Phi. Ints	**64,0**		
Consumption CEASA Rio de Janeiro 80%	20.664,3		
Consumption CEASA CantaGalo 20%	5.166,1		2.909,8
Food Waste	**2.909,8**		
Total Food Waste	**14.652,9**		14.444,7
Real Food Consumption	**14.444,7**		
BALANCE		**29.097,6**	**29.338,6**