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Abstract.

Key words: Urban agriculture, Food security, Green Roofs.

In a constantly evolving world where the vast majority of people are expected to live in urban centers, it is highly relevant to understand the elements, components and dynamics that take place within the systems, in order to provide effective interventions to achieve self-sufficiency, resilience and sustainability. Therefore, this study aims to provide alternatives by the incorporation of Urban Agriculture as a mean for contributing to food security, enhancing circularity on the use of resources, and promoting education for sustainable development., having as a reference the Metropolitan Area of San Luis Potosí, and as a case of Study the UASLP western campus. This study incorporates a sequential approach that entails a metabolism analysis of the metropolitan area, followed by an introductory analysis of the food system and policies, furthemore, narrows down with the formulation of an urban agriculture guideline for Green Roofs in UASLP, a proposal for a food security strategy, and the definition of the principles and basis for a university policy that could become pilot for the incorporation on a larger scale.

Resumen.

Palabras clave: Agricultura urbana, Seguridad Alimentaria, Techos verdes.

En un mundo constantemente cambiante en el cual se estima que la mayor parte de la población resida en centros urbanos, es de relevancia poder entender los elementos, componentes y dinámicas que ocurren en los sistemas, con la intención de poder aplicar alternativas dirigidas a la autosuficiencia, resiliencia y sustentabilidad. Por lo cual, este estudio pretende proveer alternativas a través de la incorporación de Agricultura Urbana como medio para contribuir con la Seguridad Alimentaria, promoviendo a la circularidad en el uso de recursos, y expandiendo la educación para el desarrollo sustentable., teniendo como referencia a la Zona Metropolitana de San Luis Potosí y como caso particular de estudio el campus poniente de la UASLP. Este estudio incorpora un enfoque secuencial que implica el análisis metabólico de la zona metropolitana, seguido por un análisis introductorio del sistema alimenticio y sus políticas, para culminar con el desarrollo de una guía metodológica para la implementación de agricultura urbana en techos verdes para la UASLP, una propuesta para una estrategia dirida a la seguridad alimentario, y la definición de las bases y principios para una política universitaria piloto que pueda ser incorporada a mayor escala.

Content

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Terms of reference.

BAALI: Food Bank of San Luis Potosí.

INC: Building Integrated non conditioned.

BIC: Building Integrated conditioned.

DIF: National System for Integral Family Development.

GBNC: Ground based non conditioned.

GBC: Ground bases conditioned.

GDP: Gross Domestic Product.

IMF: International Monetary Fund.

LCA: Life Cycle assessment.

MASLP: Metropolitan Area of San Luis Potosí.

MUFPPMF: Milan Urban Food Policy Pact and Monitoring Framework.

OECD: Organization for Economic Co-operation and Development.

ROI: Return of investment.

SEDARH: Agricultural Secretary of Development.

UA: Urban Agriculture.

UASLP: University Autonomous of San Luis Potosí.

UN: United Nations.

UHIE: Urban Heat Island Effect.

WB: World Bank.

WTO: World Trade Organization.

Introduction

Introduction.

The twentieth Century was characterized for the large number of events that have transformed the arrangement and the structure of the society. Technological innovations that came along with the industrial revolution made possible to maximize the use of energy and productivity in most of the sectors (industry, agriculture, transportation, etc.), which also, allowed the massive demographic growth that took place since the beginning of the century. According to some estimation (Chant and Mcllwaine, 2009), global population grew from 1.2 billion people in 1900 to 7.7 billion people nowadays.

The technological capacity acquired by the time, made necessary to allocate a larger number of people who provided labor for the industrial expansion., at the same time, in order to maintain the growing population, it was required a continuously and increasing number of raw materials that could guarantee the basic needs for their subsistence. It was then when the agrochemical industry took relevance due the formulation, use, and expansion of a large number of chemicals with the intention to maximize yields and avoid externalities such as the presence of pests. Nevertheless, the effects of the incorporation of these chemicals into ecosystems were constantly underestimated due the high number of people facing hunger and scarcity.

Right after World War II, the imperative for economic growth and development promoted by the dominant political discourse (Varoufakis, 2015) allowed, and accelerated the process of ecosystems transformation, which would allow to increase the number of resources available for the growing population and the expansion of capital by their extraction, transformation, and consumption. During the decade of the sixties, these criteria were adopted by most of the countries globally as an indicator for development and economic progress, it was argued that issues related to poverty and underdevelopment could only be solved if the economies pursue growth (Hickel, 2017), although, that could only be measured by making use of the “Gross domestic product” which make account for the number of resources that are extracted, transformed and consumed in an economy without considering environmental damages or social disparities.

Second half of the twentieth century is usually considered as the stage where human society has become a geological force of change due its constant and expansive pressure on ecosystems and pursuit of economic growth (Lewis and Maslin, 2015). Since the decade of 1960, awareness about the impacts of economic activities and capital expansion over the ecosystems and human health has risen, and with that the necessity to evaluate the severity of their impacts, along with this the urgence to be able to stablish intervention mechanisms to overcome the situation and guarantee stability for the future.

Nevertheless, growthism imperative prevailed in the following years and it was enforced during the 1980 when the globalization agenda was pushed in most countries with the intention to achieve well being and development for everybody, according to the narrative, if developing countries wanted to improve their economies and reduce poverty, they should be able to provide access to raw materials and labor that would allowed the industrial consolidation of these countries, and for the developed countries who had already gained the technical capability and economic resilience they should be able to transit to a service economy (Klein, 2007). According to this narrative, it was just a matter of time before the divide between under develop and developed countries would no longer exist, nonetheless, that gap has prevailed and even increased between countries on the global scale., technological innovation has allowed the expansion of economic activities and perpetuated economic growth around the world, however, the big issues referred to the sustainability dimensions remain unsettled. Enormous challenges for the future such as poverty alleviation, ecological degradation, economic and political disparities, and climate change prevail as the biggest thread of the century, therefore, if those issues are intended to be addresses it is important to understand the structural drivers that conforms them.

According to the United Nations (**UN**), it has been estimated that 54% of the population lives in urban centers at the time and it is expected that this number will increase to 70% by the expansion of automatized agriculture and urban expansion that accelerates migration from rural areas. Following **UN** estimations, more than 750 million in the world live under extreme poverty (classified by the international poverty line of $1.9 dollars a day) which is expected to grow by the effects of COVID-19 pandemic. At the same time, around 1/3 of world food production is currently being wasted, which could provide enough food for the society that lacks the access to it. Human Society has arrived at the time where the technological capacity to guarantee well-being for the inhabitants and achievement of sustainability is feasible, nevertheless, a shift from expansion and growthism paradigm to a reciprocity and circularity approach is essential, therefore, urban centers can perform as centers for innovation and transformation where poverty and hunger (in all of their dimensions) can be addressed properly.

At the national level, Mexico is currently facing most of these issues that are inherently connected to the economic and political system, the country with 78% of the population living in urban centers, has one of the highest rates of inequality among developing countries (Faustino *et al*, 2011), around 55% of the population lives under certain level of food insecurity (ENSANUT, 2019), diet related diseases such as diabetes, hypertension and cardiovascular illness have flourished since the last to decades to the point that has become a national health problem (Campos-Nonato *et al*, 2010), furthermore, the ecosystems are being severely disturbed by the adoption and extension of models that favour destructive practices for some sectors of the economy such as agriculture and mining, which exacerbates the displacement and migration of a large number of indigenous people to urban areas (Del Valle, 2016).

As a result of the effects on the ecosystem and the social disparities that are arising at the time, it is essential to provide the mechanisms that guarantee and mitigate their welfare, being able to provide alternatives to reduce the biggest pressure that the economic system make on them, and at the same time empowering vulnerable society in order to guarantee dignified and healthy lives within the planetary boundaries, to finally achieve sustainability.

These issues can only be approached from a multidisciplinary and interdisciplinary perspective that involves multilateral interventions in terms of all the sustainability dimensions (environment, social and economic), nevertheless, due the limitations of this study, the possibility of interventions were studied by the analysis of the concept of Urban Agriculture and their feasibility for incorporations in cities as an alternatives that aims to enhance social welfare for the citizens due their contribution to food security and health, increase resilience to climate events, providing alternative to improve the circularity on the use of resources, and providing the floor for social empowering and integration for the most vulnerable, likewise, this analysis was performed by taking the case of study, the west campus of the University Autonomous of San Luis Potosí (**UASLP**).

Overall objective.

Design an urban agriculture guideline for UASLP campuses in order to support food security, urban sustainability, and related policies in the state of San Luis Potosí.

Specific objectives.

1 Analyze the status quo of the current food supply system with an assessment of the status of food security.

2 Execute a food policy analysis of SLP making use of the Milan Urban Food Policy Pact and Monitoring Framework (**MUFPPMF**).

3 Design a rooftop urban production guideline in a case of study; UASLP western campus.

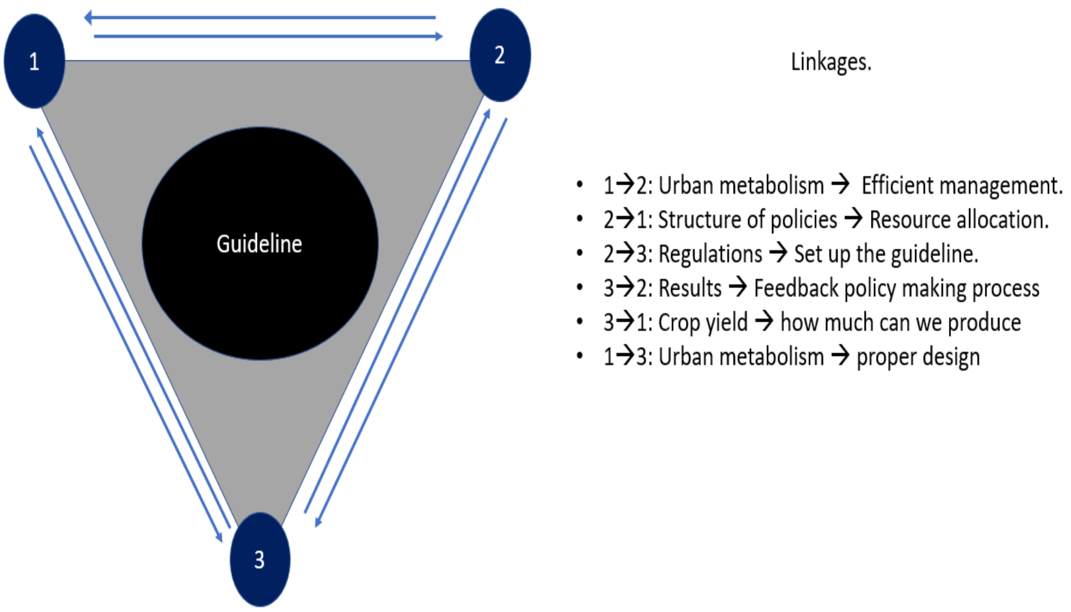

Figure 1. Connection and linkages within the objectives.

Based on the overall and specific objectives, a sequential approach was established with the intention to identify the most relevant issues and challenges for the food production system, and the stakeholder involved in terms qualitative and quantitative outcomes, this analysis would allow to understand and estimate the potential introduction of Urban Agriculture (**UA**) as an alternative for food security and climate change mitigation for the Metropolitan Area of San Luis Potosí.

For the first section of this thesis, an analysis of the urban metabolism of the Metropolitan area of San Luis Potosi (**MASLP**) was reviewed making use of a previous estimation made by Benavides (2017), based on her analysis and calculations of the water, food and energy balance, it was possible to deepen the study for the food dimension, in order to determine the feasibility and capability for introduction and incorporation of Urban Agriculture as an strategy to increase food security and health for the population. Therefore, an estimation of the total available surface either from roofs or land was performed using methods and techniques of spatial analysis and remote perception with the use of satellite images, that would allow to establish a classification of areas according to their capacity of adaptation.

Following these estimations, an explorative analysis of the food chain system and policies was performed by the operationalization of the Milan Urban Food Policy Pact and Monitory Framework (**MUFPPMF**) which is a tool that allows to illustrate an explanatory narrative about the role of cities in contributing to the transformation of urban food systems towards sustainability. The operationalization of this framework for the Metropolitan Area of San Luis Potosí, allowed the collection of a large number of statistics from different stakeholders involved in the food system (Government, NGO´s, private sector), which was also complemented by the application of interviews in order to enrich the analysis.

In the final section of this thesis, a food production guideline for green roof was developed taking the case of study of the University Autonomous of San Luis Potosí west campus, who provided important information and experience obtained since the implementation of their project “Uni Techo Vivo” in 2013. The guideline provides a sequential approach about the elements such as structure, layers, substrate, and vegetation characteristics that must be considered for the implementation of green roofs, as a mechanism that aims to improve food security, increase resilience in urban centers and empower local communities.

The arrangement of the objectives was established by the principles of connectivity and interdependency; therefore, this study aims to provide a strategy for the analysis of urban centers and their food systems (including the related policies) towards the integration of mechanisms such as **UA**, which promotes empowerment, sufficiency, resilience, and circularity.

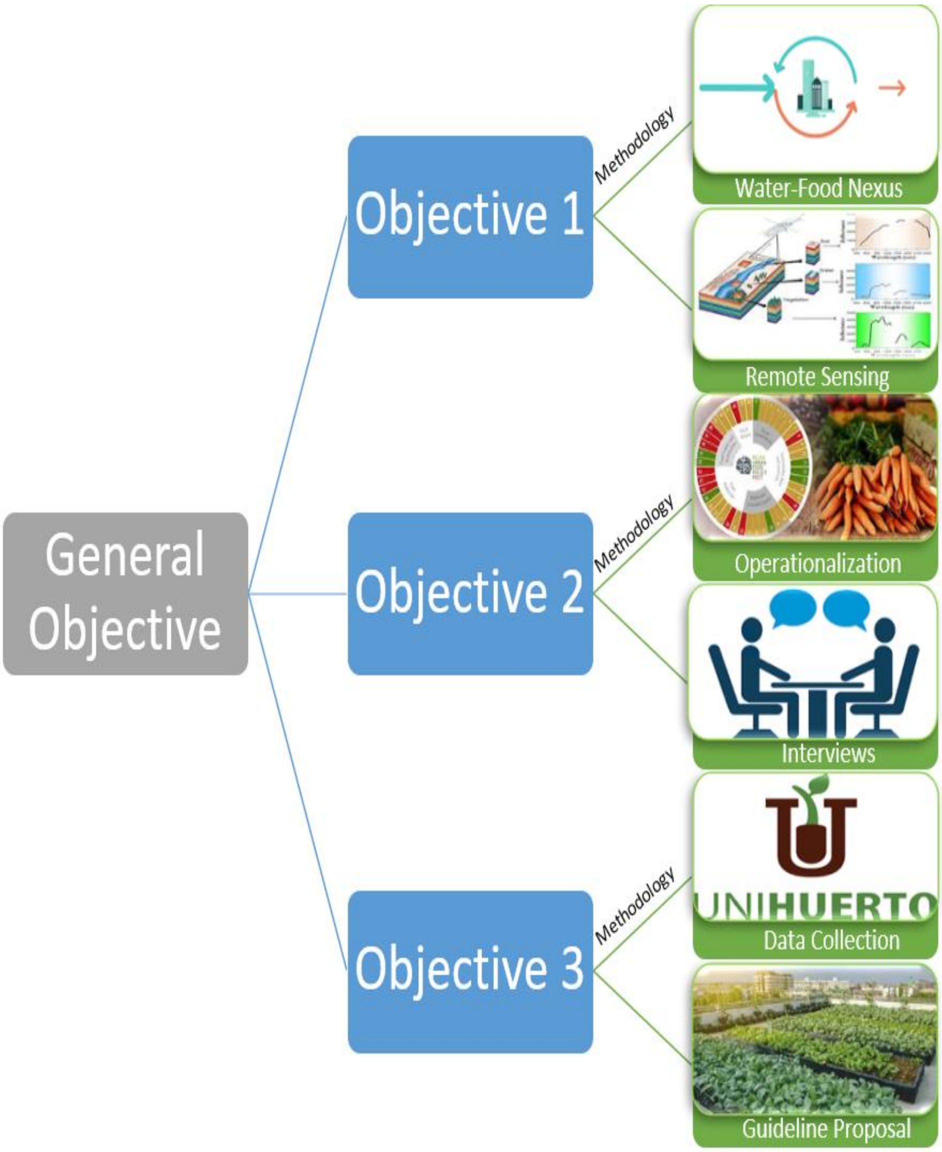

Figure 2. Structure and scope of the thesis.

Chapter 1

A brief history of the urban evolution and their role towards climate change.

Chapter 1. A brief history of the urban evolution and their role towards climate change.

1.1 The societal transformation.

The historical process of urbanization has emerged as the response to the economic, political, technological, and social drivers at the time. By the end of the XIX, the industrial revolution provided a radical transformation on the arrangement of the production and by doing so accelerating the social and political transition during the XX and XXI centuries. By the end of XIX century, inventions such as the steam engine, light bulb, and the telephone, provided a radical transformation on the industry, these inventions served as the first evidence on how access and transformation of energy could be achieved in a more effective way. This industrial revolution was also a revolution on the energy transformation capacity (Harari, 2014). Adaptation of these inventions into the wide variety of industries such as the textile, fishery, and agriculture, transformed and accelerated the productivity, and by doing so, altering the arrangement of the society. For the first time in centuries, confidence in the future was taking place, the innovations at the time were expected to be improved and provide well-being for the society and provide a long-term healthy economy. The introduction of these technologies along with other inventions, allowed to increase the productivity and the outputs of all the industries in a big proportion, these amounts of output allowed the demographic increase, which started by the beginning and until the end of the XX century. It has been estimated that global population grew from 950 million people by the year 1800, to 1700 million by 1900, and almost 6000 million people by the year 2000 (Carter, 2008).

Mechanization of agriculture and division of labor reduced the quantity of people required in rural areas and accelerating the process of urbanization by the beginning of the XX century, this expansion was only going to succeed if the technological innovations were adopted and expanded to maintain the continues fluxes of energy and matter between urban and rural areas. The expansion of these innovations such is the case of electricity and transportation lines, required massive amounts of capital, which was only possible by a large cooperation of landowners and producers, who expected to increase their profits by investing on the future model of society, these capital owners are usually considered as the pioneers of the bank system that prevails nowadays (Varoufakis, 2015).

Improvement on the energy transformation, the increase of productivity and the demographic increase created the environment for a rapid economic growth as never seen, which prevailed until the Great Recession in 1929 when a huge collapse occurred due the high levels of speculation in the United States, which also importantly affected Western European Countries due their high levels of investments in the financial sector. Enormous faith in the economic systems and growth expected in the future created the first financial crash of the XX century. During the following years the economic crisis prevailed, and the national output was importantly reduced, the government cut massively their spending and reduced labor wages with the purpose to increase the confidence on the economy, and by doing so, increasing the productivity and investment to the level before the Great Recession, but the situation did not overcome, and the situation worsened.

In 1933, when Franklin Delano Roosevelt was elected, a new strategy to overcome the crash took place with the "New Deal", whose principles were stablished by the English economist John Maynard Keynes, who proposed that in order to maintain a healthy economy, boundaries, limits and principles had to be stablished to avoid an inevitable crash, which happened when the economic system is left to run alone by the principle of profit (Keynes, 2018). By his principles and interventions, a massive governmental employment program was run, the market started to be regulated towards social ends and the stability of the economy prevailed. The adoption of his policies (mostly in the US and Western European Countries) created the environment for a rapid economic growth environment, where the purpose of the increase on wealth was mainly addressed to the social well-being.

The dark image of the Great Depression prevailed as a ghost for the governments, and it was necessary to identify the leverage point for intervention to prevent it. Simon Kuznets who was an economist at the National Bureau of Economic Research, presented in 1937 his formulation of the "Gross domestic product" nowadays usually referred as **GDP**, as a measure to capture all the economic production by all the participants in a single measure (Piketty, 2018).

This measure was rapidly adopted as an indicator for measuring the performance in most of western economies at the time, nevertheless, the same Kuznets mentioned that this should never be seen a measure of progress since it does not consider the impacts created by the economic activities and neither the social well-being nor progress.

Nearly finished World War II, the Bretton Woods Conference took place in 1944, where the new economic system, and policies were discussed and adopted by 44 countries, the main idea was to stablish a dollarized system that promoted the collaboration of countries and the expansion of the markets. Institutions such as de World Bank (**WB**) and the International Monetary Fund (**IMF**) were stablished, with the purpose to measure the stability of the system and provide affordable credits for the countries facing contraction and deficiencies on their economies. It was then at Bretton Woods that GDP measure was commonly adopted and perused as a progress measure for the participant countries.

These new economic policies intended to improve human well-being around the world., poverty, hunger and violence were latent issues in the global south and it was required to take measures against it. In 1949 when Harry Truman took the presidence of the United States, globallization ideas were introduced as one of his main pillars, if the world intended to become a better place, it was required to develop strong economies through the global collaboration, it was then where the developmentism idea was first stablished (Taylor, 2015).

For the following years, Keynesian ideas were predominent, important achievements were taking place in many global south countries such as the rise in salaries, reduction of inequality, improvement of the health systems and political empowerment of society. Development ideas were taking place with the usea of Keynesian Policies such as tariffs on imports, subsidies for local industries, and protection to the labor force were still at place (Hickel, 2017). The idea of economic growth as the driver for social enhancement was strenghtened when the Organisation for Economic Co-operation and Development (**OCDE**) was created in 1961, which had the purpose to design and promote policies to guarante the high sustainable economic growth.

By the year 1971, the Bretton Woods economics system was dissolved when the United States and Wester European countries faced a combination of high inflation and economic statnation, which according to some analysis (Varoufakis, 2015, Raworth, 2017), took place due the absence of a recycle mechanism of value among the countries, and also by the political implications at the time. It has been argued that the colapse of the system was proportionally accelerated by the armed conflicts in South East Asia.

In 1972, an oil crisis took place when the Organization of Arab Petroleum Exporting Countries claimed and embargo for a large number of countries where the price of oil rose nearly 300% from $3 to $12 us dollar globally (Knittel, 2014). A large proportion of global south suffered a huge increase in their levels of debt, which became impossible to repay, by 1982 the level of debt quadrupled from $400 billion in 1970 to $1.6 tillion US dolar (Arsenault, 2014).

Economist at the time, such is the case of the Austrian-British Friedrich August von Hayek and the american Milton Friedman, argued that the failure of the system came from the level of intervention on the markets, according to their ideas, if freedom and well-being were expected to be provided worldwide, the interventions on the markets had to be erradicated, and in 1976 The Royal Swedish Acadmy of Sciences awarded Milton Friedman the Nobel Price for his monetary history and theory ,and for providing a demonstration about the complexity of stabilization policies.

The level of conflicts at the time in the US and Western European Countries, the increasing levels of debt in most of the global south countries, and the political conflicts that were taking place at the time provided the opportunity from the economic transition from the Keynesian model, which aimed to provide a social well-being system that worked by the intervention of the state in the market, where the wages were rising since the beginning of the New Deal, inequality decreasing and economic growth prevailed to decades, to the economic arrangement proposed by Milton Fridman and Friedrich August von Hayek commonly known as the neoliberal stage.

If the market was expected to provide well-being and a better future for the society, it was required to make a global commitment to collaboration, according to their ideas which they refer mainly to Adam Smith principles, the market can only provide the best when it is run completely free and withouth the intervention of the state. The globalization principles were settled, and the expansion and rearrengement of the production systems started to take place. These principles were strongly expanded in the decade of 1980´s in the US with the president Ronald Reagan and in the UK with the prime minster Margaret Thatcher, who reinforce the liberal markets ideas and promoted the expansion of foreing capital to global south countries, and ease the government intervention in their own countries. The economic principles adopted and promoted by them were addressed to persue economic economic growth rather than social-being, if the economic wealth was achieved by private intervention it was unnecesary for the state to get involve in the process, economic growth was the future or the collapse.

The high levels of debt and the political conflicts ease the possibility for intervention and transformation on most of the global south countries (mostly Latin America, Africa and some parts of Asia), who were not able to repay their debts which exponentially grew dure the oil crisis, and it was then when the **WB** and **IMF** intervened to rearrenge their debts, but in order to do it they would have to impose structural adjustment programms., the structural adjustment programs included cutting down protective tariffs and subsidies for local industries, reducing social spending (mainly health and education), easing labor policies, privitization of national industries and free access to foreign profitable investments, in the promise of economic growth and poverty reduction (Klein, 2007). Nevertheless, it has been estimated that global south countries lost an average of $480 billion per year in potential GDP during the structural adjustment period (Stern, 2007). By the end of the century, for most of the people in Latin America the standard of living was lower than it was in 1970, when the levels of GDP highly increased (O´Neil, 2015).

Urban centers were transformed by this transition in the economic structure, most of the industrial activities that were located in most of the global north countries was relocated to global south, where the salaries and raw matterial were cheaper and easier to access. Migration of industries occurred mostly during the 1990´s across US and Europe, and their economies were addressed into the service industry. For global north countries, which most of them had already developed a strong governance capacity, many of the principles of the Keynesian economics were prevailed, and their urban centers were redesigned according to the well-being principles, the population growth slowed and the migration was reduced. In global south countries which were deeply dependent on their primary sector, were transformed by the private investment promoted by the World Trade Organization (**WTO**), which accelerated the migration process to urban centers where most of the industries were located.

Along with the expansion of foreign industries, an expansion of informal settlements, social displacement, increase of economic disparities, and socio-spatial fragmentation took place in most of developing countries. Pursuit of economic growth as the criteria for development in the absence of strong governance due the political conflict, which provided the stage for the highly unequal and problematic societies that prevail nowadays.

Since the adoption of these policies, the levels of GDP have rose exponentially all across the world, the levels of extraction and transformation of raw materials have reached historical levels and the levels of poverty have remained or even increased (Hickel, 2016).

Over the course of of the past four decades since 1980, the daily income for the vast majority of people has increase only by an average of 2 cents per year (Hickel, 2020). By the same time the difference in the level of income from rich countries increase from a ratio of 32 to 1 times more by 1960 to a ratio of 134 to 1 by the year 2000 (Easterly, 2001). By 2013 the final report of the Millenium Development Goals was published, claiming that poverty had been erradicated by half and if the development of countries was expected to continue, these policies had to be preserved. Nevertheles, critics about these achievements were made in the base of the methodology applied, and the standard poverty measure used of 1 dolar a day. Several schoolars argue that 1 dolar a day should not be used as criteria for assesing poverty, if a dignified and decent life is aimed to be achieved it should be below 5 (Edward, 2006) or even 10 dolars a day (wich is the boundary established by the world bank). When this criteria is adopted the headcount overcomer and nearly 4.3 billion people which represents more than 60% of the global population nowadays (**Figure 3**), live under certain level of poverty and most of the achievements of porverty come from China, and it was not due the liberalization policies (Hickel, 2016).

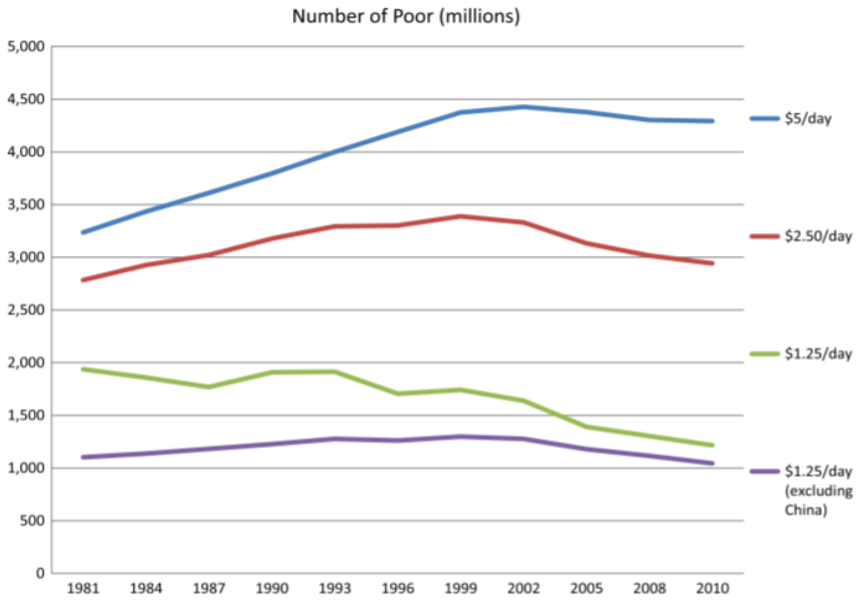

Figure 3. Historic evolution of income globally (Hickel, 2016).

Important achievments since the decade of 1980´s have been possible in the field of health, technology and education, but we have come to the point where the feasibility to erradicate issues such as poverty, child malnutrition and low life expectancy among others is affordable. Large amounts of wealth have been achieved by the transformation and division of labor across the world, although, the promise of a globalized future where well-being is accesible for everyone has been left a side in the name of profitability. Several scholars are currently discussing about the need of a new global plan that could transform and reverse the levels of inequality and the same time reducing the levels of poverty increased during the last 40 years.

Deliberating the future requires an integral approach that indentifies the root cause of the current arrengement of the society, identify what are the main drivers that allowed the issues at the time and be able to locate leverage points for intervention. The last two centuries have dramatically changed the structure of the society and impresive achievement have been possible with the development of technology and the introduction into the economic system, nevertheless, it is always important to step back at a the point where the issues of the future are identified, and be able to democraticly delibarate the inclusive and fair solutions that come along with sustainability.

1.2 The environmental implications.

Along with the industrial revolution and the technological achievements that characterized XIX and XX centuries, an exponential demographic growth took also place at the time. Mechanization of production and the adoption of technologies that massively increased the production allowed the subsistence of a larger amount of people that were required in urban centers to provide labor to industries. Technological achievements in the field of agriculture optimized the yields at a lower price by the introduction of synthetic fertilizers, pesticides, and machinery. The increasing population demanded a larger number of raw materials to be extracted and transformed to fulfill the requirements for subsistence, and that capacity of transformation was finally possible to measure with the adoption of the Simon Kuznets indicator (**GDP**), nevertheless, as he mentioned it was never meant to be proposed as an indicator for progress due its inability to point out the environmental damages occasioned for the economic activity. In 1962, the American marine biologist Rachel Carson published her book named Silent Sprint, where she collected evidence about the environmental implication of the expansion of the chemical industry in agriculture, and the indiscriminate use of pesticides and fertilizers. She was one of the pioneers to point out about the relevance of the understanding of complex systems and the interrelationship among environment and human health. Her book opens the stage for the environmental movement that begun in that decade, and ever since then more awareness about the environmental implications of economic activities has been achieved.

On the other hand, this movement allowed a new era for policy development for the regulation and establishment of guidelines that required a deeper research about the effect of the large amount of chemical released into the environment.

As previously mentioned, when **GDP** was adopted as the measure by a large proportion of countries with the creation of **OECD** in 1960, the levels of ecosystem transformation rose continually in order to provide raw materials and fulfill economic growth. Globalization agenda was expanding rapidly, and the promise was that poverty eradication and achievement of social well-being was only possible by opening the markets and expecting economic growth.

The effects of the rapid transformation of ecosystems and the inconsistency for growthism as a metric for human development and economic stability were publicly evident in 1972 when Donella Meadows published “The Limits to Growth” report which consisted in a computer simulation about the feasibility of the economic activity, population growth and environmental transformation for the future.

The premise at the time was that the innovation and technology development were going to make possible to maintain a perpetual economic growth and by doing so, social struggles were going to be alleviated, furthermore, this report served as the first evidence to critic this logic and demanding for delimitation on the use of finite resources, which afterwards, opened the debate of sustainability.

Furthermore, with the promoted policies at the time, the increase on the transformation of ecosystems got to the point where the human activity has become a geological force of change., twentieth century came to be the historical time where the climate stability that prevailed during the last 12,000 years has been modified due the rapid rate of environmental transformation in the requirement for goods to prevail economic growth. Beginnings of the 1970´s can be considered as the transitional period of time where climate stability that prevailed during the Holocene has change to an uncertain and unstable climate period for the future, an era denominated as Anthropocene.

According to the Millennium Ecosystem Assessment (2001) more land was converted to cropland in the 30 years after 1950 than in 150 years between 1700 and 1850, some 35% of mangroves have been lost, 20% of coral reefs destroyed, extinction rate are 1000 times higher than before the industrial revolution, genetic diversity has declines globally, biodiversity and ecosystems services are on decline, and weather climate events were consistently higher compared to previous times. Reports made by United Nation scientist have found that 40% of the planets soil are now degraded due certain kind of human activity, agricultural soil is being lost more than 100 times faster that is being formed (IPCC, 2018).

Despite these facts, the economic growth imperative prevails in most countries around the world and the necessity to stablish limits for use and transformation takes minor place in the political debate, expectancy in an innovative revolutionary technology is expected to solve the future challenges without a deep understanding of the elements involved and the boundaries of the system.

In 2009 a research team of environmental scientists led by the Swedish professor Johan Rockström published a framework to define the safe operational space for humanity where they identified 9 essential boundaries to be prevailed if sustainability is aimed to be achieved, these 9 boundaries linked to earth system processes are: 1) Climate Change, 2) Biodiversity loss, 3) Biogeochemical, 4) Ocean acidification, 5) Land use, 6) Fresh water, 7) Ozone depletion, 8) Atmospheric aerosols and 9) Chemical Pollution. Stablishing boundaries provides a shift to the conventional approach from governance and management, emphasizes the importance of the prevalence and restauration of the natural processes that have been modified from the expansion of productivity. According to the last estimations, currently 4 boundaries limits have already been surpassed which represent a potential thread for the homeostasis of the planet.

The planetary boundaries framework provides a complex system approach where every single component interacts, adapt, and relate in lineal and non-lineal ways, emerge, and feedback each other. The main focus from the study of system complex is to reach the capability to identify leverage points for intervention; nowadays, we have come to the point where climate change represent the biggest threat for the subsistence of the human specie in all of its history, and that have come along with the accelerated transformation rate of ecosystem for human use, it is undeniable that any human activity involves an environmental impact, nevertheless, if sustainability is aimed to be achieve for the future, understanding and delimiting the system (in terms of resources) is essential.

One example for this is the global material footprint which, represent the amount of raw material extracted and transformed into goods required for human subsistence and well-being, and plays and important role in each one of the planetary boundaries proposed by Rockström, estimations about the optimum levels of extraction from ecosystems that guarantee their proper function and maintenance are in the order of 50 billion tons per year (Bringezu, 2015), furthermore, recent evidence show that the current global material footprint is nearly 100 billion tons per year (**Figure 4**). The same study points out that a global sustainable material footprint per capita is about 8 tons per person, which many of high-income countries already surpass that number from 2 to 4 times more.

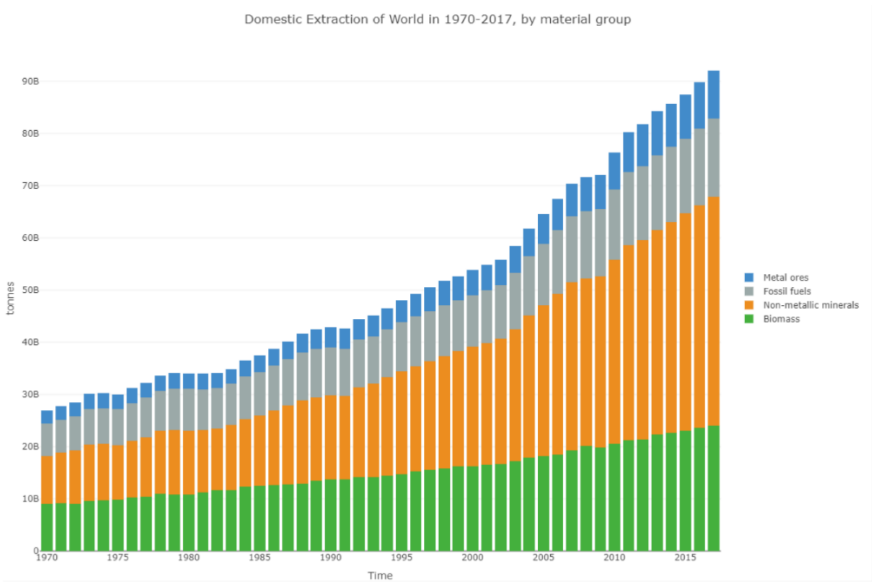

Figure 4. Global Material Footprint from 1970-2010. Source: materialflows.net

Economic growth pursuit as the metric for development, and as strategy to alleviate social issues represents a bigger thread due the correlation level with global material footprint (**Figure 5**). Arguments about decoupling economic growth and global material footprint to enhance green growth are currently gaining relevance in the political debate, it is commonly argued that when high level countries get higher levels of education and well-being, they start to increase awareness and reduce their consumption in terms of domestic material consumption, nonetheless, it does not include the resources involved from the production of the goods which are mainly done in developing countries. Evidence points out that in order to provide a proper a consistently approach towards climate change, expansion of the economy is unreliable and leads to the ecological collapse.

Economic growth remains relevant for a large number of developing countries where they lack the basic means for a dignified and meaningful life but the interventions that really matter when it comes to improving human welfare do not require high levels of GDP (Hickel, 2020), but in high income countries gets to the point where further increases on human welfare are unrelated to the increase on income.

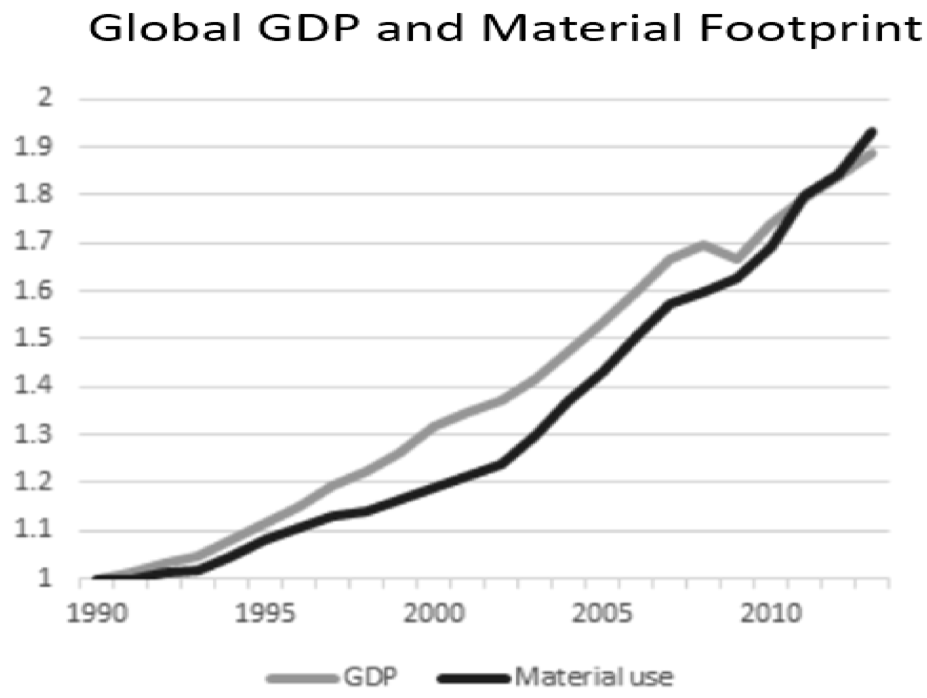

Figure 5. Correlation of GDP and Material Footprint (Hickel, 2020).

Climate change is already having tremendous effects all around the world, and global south countries remain so vulnerable even when their contribution to the problem has been minor compared to global north countries. Data from 2010 indicates that 400,000 people died that year due to crisis related to climate change (Climate Vulnerable Forum, 2010)., if the levels of greenhouse gas emissions continues at the rise, it is expected that an increase of more than 3 ºC might occur globally which will transform and disrupt the ecological balance, accelerating the dispersion of diseases such as malaria and dengue in larger areas, increase on the extreme weather event rates and disruption in the biochemical fluxes that influence the stability of our means of subsistence. According to the Climate Vulnerability Monitor data, global south stands for 82%

of the total cost of climate breakdown and it is expected that the cost will expand to 92% in global south countries, amounting for $954 billion. It has also been estimated that activities related to material extraction are responsible for 80% of total global biodiversity loss (International Resource Panel, 2019). A drift in the paradigm for the future is required, if extreme climate change and ecological collapse are intended to be avoided, understanding the underlying process that come along with the economic activities and intervene in a meaningful way that achieves social well-being for the whole society within the planetary boundaries is essential to finally achieve environmental sustainability for the future.

1.3 Food security and social well-being among urban centers.

Among the different drivers derived from the industrial revolution and the division of labor, the transformation of agriculture was one of the main elements that allowed the establishment of a higher number of people working in diversified and specified activities. In 1910, the German Chemistry Carl Bosch, was able to develop a new process for synthesizing ammonia from hydrogen and nitrogen, the process had the intention to mimic the natural process of nitrogen fixation made by plants. This process was able to manufacture in an economically feasible way ammonia (Britannica, 2020), which transformed the field of agriculture and the formulation of fertilizers.

Many innovations came together with the adaptation of this process, which gave birth to the fertilizers and pesticides industries, the historical paradigm was then feasible shifted from the understanding of nature to the introduction of technology towards undefinable limits for production. This technological approach provided the place for a large formulation of chemicals that aimed to control some of the externalities of agriculture without negative effects, nevertheless, it was uncertain to identify the potential hazardous at the long run and the negative effects on soil, biodiversity, and human health, since there was no means to assess them. One evident example is the case of Dichlorodiphenyltrichloroethane, commonly known as **DDT** which was massively adopted for pest management in agriculture in 1939 due the supposed effectiveness and inertia on human health, for whom Paul Muller was awarded with a Nobel prize.

This approach underestimated the complexity and the large number of effects for the application of unknown substance, only with the purpose to increase yields, and many catastrophes occurred from the large use of these substances in terms of disease, soil depletion, disruption of biogeochemical cycles, chemical dispersion, and death (Carson, 2002, Shiva, 1991). However, important achievements were made and for the first time in history, agricultural outputs prevailed and increased, which represented hope for the growing population at the time that lacked the basic means for subsistence and nutrition, along with the economic drivers at the time, the logic for growth prevailed but represented a huge ecological cost.

In 1941 the Rockefeller Foundation which at the time was one of the biggest investors in the agriculture sector settled the seed for the Green Revolution that took place during 1960-2000 mainly in Mexico, Pakistan, and India., when they launched their first pilot research project on agriculture with the purpose to identify opportunities for transformation and adaptation of traditional agriculture into profit-led industries in global south. The Chemical industry was on the rise in the US, and it have provided important achievements on the national agricultural outputs, nevertheless, this transformation was finally shaped in 1954 when Norman Bourlaug, which was one of the main collaborators of the Rockefeller Foundation began to innovate disease-resistant and high yields crops using genetic modification (Sumberg, 2012). It was then possible to close the circle of the new technological approach, composed by genetically modified seeds, resistant to pesticides, and capable to absorb the massive number of synthetic fertilizers that the industries were providing as a whole kit for farmers around the world.

During the following years, the green revolution was extended to a large number of countries around the world with the intention to create peace and prosperity, this transformation on the agricultural systems for most of the developing countries from subsistence to profit-led transformed the social, economic, and political arrangement. This was also possible due the predominant liberalization policies at the time that allowed the introduction of technologies and investments from foreign industries that promoted the massive use of fertilizers, improved hybrid seeds, state support and access to credits. According to some estimations

(Conway, 1997), total food production in developing countries more than doubled between 1960 and 1985, nonetheless, for most of the western countries the number of hungry people increased by more than 11% (Rosset *et al*, 2000).

Green Revolution provided the stage for the massive migration of peasants to urban areas due the inequalities of the market. The high-technology agricultural industries radically transformed most of the economies on developing countries, where the farmers were not able to compete with large producers who were strongly subsidized by foreign capital. The current paradigm of economic growth made possible to largely expand agricultural land for large corporations that possessed the resources to implement and incorporate large amounts of inputs into the soils. Transformation of food from a mean of subsistence and a social act into a commodity has contributed to the environmental challenges of the present and the future without contributing to the social well-being for the majority of global world population, and additionally to the subsistence of the ecosystems.

The historical narrative usually points out about the large achievement in ambiguous terms, the biggest part of the agricultural transformation that took place in second half of the twentieth century was pursued with the intentions of eradicating poverty and providing a better life from everyone, rather than that, the accumulation of capital and perpetuation of growth for large corporations took place. In 1974 the first United Nations Food Summit took place in Rome with the promise to eradicate hunger within a decade, it was essential the multilateral cooperation and the expansion of the technological approach in order to achieve self-sufficiency in the world. According to their statements, it was required to enhance the productivity of agriculture by adopting agroindustry practices and the effective policies. If poverty was meant to be eradicated, it was required that high income countries would get involved providing the technology and assistance that would allow the increases on yields.

For the following years the investment and expansion of agroindustry's around the world increased dramatically but it was required to stablish a coherent metric to evaluate the health condition of the society and their accessibility to nutritious food. By 1996 a larger number of countries attached to the World Food Summit to collaborate towards the eradication of hunger, and it was then when the concept of food security was first adopted and defined as:

“A situation that exists when all people at all time have physical, social and economic access to sufficient, safe and nutritious food to meet dietary needs and food preferences for an active and healthy life”.

By this definition, four dimensions of can be identified:

Availability: Food availability addressed the “supply side” of food security and is determined by the level of production, stock levels and net trade.

Access: An adequate supply of food at the national or international level does not in itself guarantee household level food security. Concerns about insufficient food access have resulted in greater policy focus on incomes, expenditure, markets, and prices in achieving food security objectives.

Utilization: Utilization is commonly understood as the way the body makes the most of various nutrients in the food. Sufficient energy and nutrient intake by individuals are the result of good care and feeding practices, food preparation, diversity of the diet and intra-household distribution of food. Combined with good biological utilization of food consumed, this determines the nutritional status of individuals.

Stability: Even if your food intake is adequate today, you are still considered to be food insecure if you have inadequate access to food on a periodic basis, risking a deterioration of your nutritional status. Adverse weather conditions, political instability, or economic factors (unemployment, rising food prices) may have an impact on your food security status.

(FAO, 2009).

Nevertheless, the current policies at the time were oriented only on high productivity without considering the losses in nutrients, the effects of the expansion for massive requirement systems, the social enclosure by the disruption in local markets, and the effects on the ecosystems. The expansion of industries and the transformation of food chain for profit-led purposes made possible the nutrition transition that took place since 1990´s which was characterized by altering social habits and diets into richer, more complex, sweeter, fattier, processed foods, which in turn generated diet-related ill-health patterns associated with affluence (Popkin, 2001).

With the financial crisis of 2008, a global food spike-price took place when many of the investments were addressed to the food industries, but it mainly affected developing countries where there were already so many issues regarding poverty and food access. Continued that year, a “High Level Task Force on Global Food and Nutrition Security” (HLTF), was stablished by the United nations with the purpose to stabilize and ensure that the financial institutions and the World Trade Organization provided a robust and consistent support to countries struggling to cope with food insecurity, which according to FAO´s estimation 1.023 billion people were currently facing hunger. The notion that a combination of science and technology, capital, and investment were the basis for alleviation prevailed, and the agroindustry´s expanded globally with the intention to provide global food price stability.

Nowadays, the scarcity narrative prevails in the political and economic debate, it is argued that still most of the farming systems from developing countries require a transformation if poverty and malnourishment is aimed to be eradicated, that the adoption of strategies such as the use of synthetic fertilizers, pesticides and genetically modified seeds are able to provide those benefits. During the last 50 years the narrative of eternal expansion and growth has prevailed, and nowadays represents one of the main drivers towards climate change. The change of policies that allowed globalization transformed the way on how the ecosystems are seen only as a source of raw materials without providing benefits for the vast majority of people.

The transition process from agricultural into industrial societies that has taken place in many developing countries, has accelerated the growth of urban centers, and their dynamics have dramatically affected the health of the citizens, where they are led to adopt sedentary and unhealthy habits, to the point that globally one in five deaths are associated with poor diets (GBD, 2017). At the time, when the levels of poverty and food insecurity are rising, the amounts of food that is wasted is also growing, according to FAO (2017), one third of food global production is wasted during any of the process from harvest, processing, distribution, and consumption (**Figure 6**).

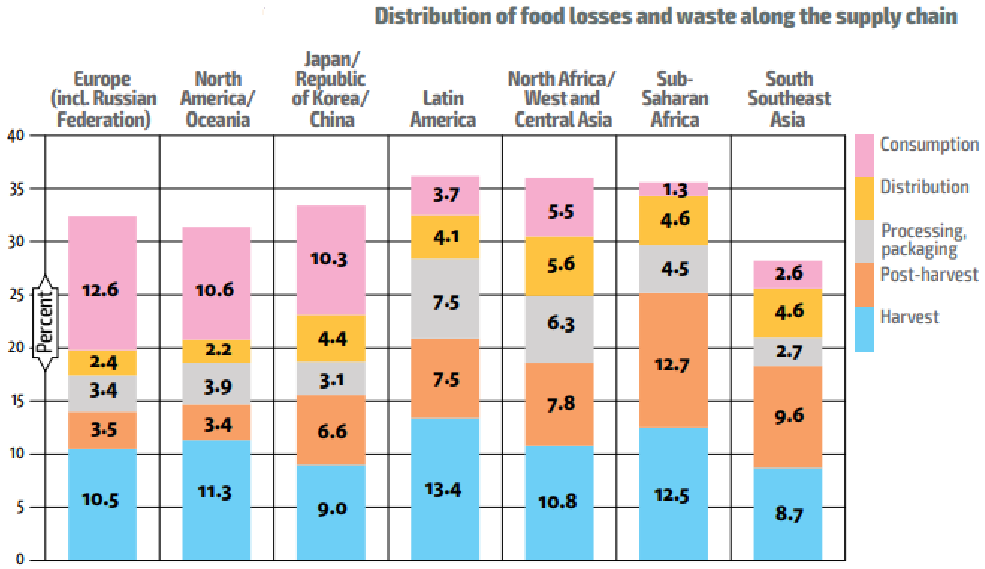

Figure 6. Global food loses (FAO, 2017).

A shift on the dominant paradigm of perpetual growth and unrestrained production is required if the challenges of the twentieth one century are aimed to be tackled properly, issues such as climate change, soil depletion, biodiversity loss, deforestation, poverty, malnutrition can only be addressed with a holistic approach with the purpose to guarantee social well-being. Principles of regeneration, cocreation and reciprocity are required to be stablished from the conventional spirit of domination and extraction.

Food insecurity is not a problem associated to lack of production, it is a problem of inadequate access to resources as a result of poverty, and if this is aimed to be transformed, urban centers will play an essential role in the food revolution that is required for the future when the vast majority lives there, and almost 70% of global resources are consumed within.

1.4 The Urban Agriculture revolution.

It is expected for the future that most of the population in the world would migrate to urban centers due the automatization and displacement or rural areas, which has occurred since the establishment of the policies that promoted globalization and development. As previously mentioned, this process has transformed the arrangement of the societies in global south where the expansion of urban areas and the impacts associated remain relevant. For many countries in global south, population growth prevails due the lack of job opportunities in rural areas which at the same time promotes the expansion of informal settlements that lack the basic infrastructure for a dignified and healthy life.

Pursuit of economic growth as the main goal for governments, promote the expansion of strong private capital which argues for the privatization of public space and expansion on the resources extraction for industries, which has become a thread due negative effects on the surroundings ecosystems, the sealing of surface, lowering of groundwater, pollution by waste, and additionally due the lack of governance capacities for mitigation, the increase on the levels of vulnerability to catastrophes.

There is an urgent demand for urban policies that promote holistic approaches for the complexity and the number of dimensions that cities involve. Empowerment of the institutions that allows and promote the social inclusion and participation is essential for the enhancement and pursuit of sustainability.

It is essential to tackle the main issues mentioned such as poverty and malnutrition of the population before moving forward on the agenda, nevertheless, the intention of this thesis is to provide an explanatory narrative about how the adoption and introduction of strategies such as **UA**, could provide a multidimensional approach that is able to introduce a large number of benefits for the issues that prevail in urban centers.

Chapter 2

Defining Urban Agriculture.

Chapter 2. Defining Urban Agriculture.

2.1 The relationship between agriculture and cities.

For more than 2500 years of history, the creation and establishment of urban centers have been possible due the closeness with essential resources such as food, water, and energy for the maintenance of their citizens. Inventions that came along with the industrial revolution in the XIX century made possible to rearrange the structure of the cities, the revolution in the transformation of energy made possible to expand and increase the agricultural outputs for the growing population at the time. The incorporation of fossil fuels by the beginning of the XX century made possible to spur urban density, increasing the extensive construction and making the transportation feasible and profitable. Nonetheless, Urban agriculture has become relevant during times of high uncertainty and scarcity. This is the case of the Victory Gardens which were largely adopted for food production within the urban areas during World War I and World War II, which were able to provide almost 40% of the national vegetable intake. More recently it has been noted how the expansion of these practices have rose globally due the effects that the economy takes on the food system, by instance, Portugal saw an exponential increase on urban agriculture since 2010 because of the global food price increase (Ferreira et al, 2018), the contributions of **UA** are highly relevant, to the point where more than 200 million urban residents are currently involved in the food production systems.

The disruption on the systems that comes along with the urbanization process, has created a large number of problems that involve the most relevant aspects for human welfare. Therefore, a reintroduction and expansion of the food production systems within the cities, aims to become a major alternative to mitigate the effects of the urban expansion, contribute with the food security and sovereignty of the dwellers, recover the ecological structure (in terms of ecosystem services), promote the biodiversity, preserve the local diversity, and achieve sustainability trough the adoption of circular approaches on the use of resources. Social awareness about the implications of the food system and the urban lifestyle is essential for the changes that are expected for the future, and **UA** can become a large alternative for education, inclusiveness, and resilience.

2.2 Defining Urban Agriculture in 21st century.

As previously discussed on Chapter 1, urban centers have been continually transforming due the external or internal drivers that constitute them such as environment, economy, and politics.

Urban development fragments, isolates, and degrades natural habitats; simplifies and homogenizes species composition; disrupt hydrological systems and modify energy flows and nutrient cycling (Alberti, 2003). They are usually characterized by scholars as highly dependent heterotrophic systems that depend on large inputs of energy and matter and, also possess an immense amount to absorb emissions and waste. It is important to provide an operational framework for the UA alternative if the issues involved within the urban centers are aimed to be mitigated and solved. Therefore, for the purpose of this thesis, the concept adopted is the following:

Urban agriculture can be defined as an industry that processes, and markets food, fuel, and other outputs, largely in response to the daily demand of consumers within a town, city, or metropolis, on many types of privately and publicly held land and water bodies found throughout intra-urban and peri-urban areas. Typically, urban agriculture applies intensive production methods, frequently using and reusing natural resources and urban wastes, to yield a diverse array of land-, water-, and air-based fauna and flora, contributing to the food security, health, livelihood, and environment of the individual, household an community (Smit, 2001).

2.3 Urban agriculture and ecosystem services.

The concept of ecosystem services has been recognized as a contemporary economic tool to stablish an economic value to the notion of ecosystem values and the benefits that human societies obtain from them. The first notion of ecosystem services was developed by scholar George Perkins Marsh in 1864 with his publication of Man and Nature (which was also one of the first critics of the idea that America´s resources were infinite), where he realized the implications of soil depletion, and the associated effects over the Roman Empire. He first realized how the transformation of environment would disrupt the balance and the subsistence of resources obtained from them such as water, fibers, wood, and food.

Despite of this, it was not until 1935 that the term ecosystem was first presented by Arthur Tansley on one of his articles named “The use and abuse of vegetational concept and terms” which was then stablish as one of the fundamental concepts of modern ecology. Following, in the decade of the 60´s, the environmental movement start to take place in the political sphere with the publication of Rachel Carson´s Silent Spring in 1962, which made a compliance of a wide variety of studies that evidenced the potentially dangerous effect of the use of chemicals in agriculture, how the expansive use of them disrupted the ecosystem processes and represented a potential hazard to human health.

Efforts to identify and quantify the beneficial function of the ecosystem flourished during the next decades in order to provide a reference into de public debate of ecological conservation, in 1971 the report of The Study of Critical Environmental Problems (SCEP, 1970), approached these issues and schematized a variety of services required for the proper functioning of the ecosystems such as: pest control, pollination, fisheries, climate regulation, soil retention, flood control, soil formation, cycling of matter, and composition of the atmosphere. Some other utilitarian approaches (Westman, 1977., Ehrlich and Ehrlich, 1981) tried to quantify the beneficial functions of ecosystem services for the society in order to increase the public interest.

The adoption of ecosystem services by the Millennium Ecosystem Assessment contributed to put the discussion in the policy agenda, and ever since that, the ecosystems services literature has grown exponentially (Gómez-Baggethun, 2010). Nowadays, ecosystem services are one of the main elements to be considered for stakeholder who aim to evaluate the positive of negative impacts on process that involves the transformation or regulation of ecosystem, this being possible through the use of Market Based Instruments such as Markets for Ecosystems Services and the Payments for Ecosystem Services (Pagiola, 2008).

One of the main goals of **UA** is to recover the ecological structure that has been lost through the process of urbanization, the understanding of that structure can be analyzed in terms of biodiversity in all its complexity, nevertheless, for the purpose of this thesis, some of those elements were described and summarized from the literature in terms of the ecosystem services that go from: provisioning, supporting, regulating and cultural.

2.3.1 Provisioning Services.

Contribution to Food Security.

There is currently a big debate on the estimate contribution of **UA** to food security in urban centers. According to FAO, there are currently 2.4 billion people living under certain level of food insecurity, and at the same time almost 40% of global food production is wasted during the whole process. Following the forecast and estimations of growth in urban centers in the next decades, it is essential to improve, and relief the pressure that the conventional industrial agriculture sectors make on the environment. During the decade of the 90´s, it was estimated that 200 million urban residents produce food for the urban market, providing 15 to 20% of the total world supply (Ferreira *et al*, 2018), although, due the complexity of each one of the urban centers, and the dynamics that modify these patterns (such as macroeconomics) these numbers are constantly changing.

However, **UA** is gaining recognition as a feasible strategy for urban poor society to reduce the reliance of income to get access to food, which may represent 60 to 80% of their income (Maxwell *et al*, 1998), at the same time, it is able to improve the health of the producers by the adoption of good practices that ensure the dietary quantity and quality, and by doing so also reducing the average intake of highly processed meals that are currently affordable at cheaper prices, which are overloading the market mainly in global south countries. Identify the potential contribution of **UA** to the cities in the XXI century is now a big issue to estimate and be aware of, studies made by Zezza and Tascioti (2010) found that the proportion of UA according to the actual agricultural yields might be from 3 to 27% of global food supply which might depend on the arrangement and the practices adopted. Some other optimistic estimations (Goldstein *et al*, 2016), assert that 100% of global food need could be provided by transforming 40% of urban land at the current yields. It is clear how **UA** can play an important role in urban development, and it is increasing importantly in poorer countries where the contribution to food security is more relevant, it is essential to develop a holistic approach for the food production in urban centers that promotes social inclusion, enhance health and food democracy and achieves sustainability.

2.3.2 Supporting Services.

Water Quality Enhancement.

Urban centers are characterized by their high levels of disruption on the ecosystems, the transformation of land reduces the amount of infiltration, increases the levels of runoff water, and maximizes the risk for contamination. **UA** aims to partially recover the ecological structure of the place, transforming the landscape, and reducing the vulnerability of the cities, it can be understood as a building resilience strategy that involves a wide variety of elements from infrastructure, economics, political will and environmental sustainability. The recovery of vegetal land can improve the quality of the water by removing many pollutants (such as heavy metals) and providing a healthier environment.

For the case of Green Roofs which are gaining relevance as a climate change mitigation strategy, studies made by Vijayaraghavan and Raja (2016) showed the relevance and potential contribution according to the kind of substrate, they analyzed a low-cost substrate made with perlite, sand, vermiculite among other materials, and found a well performance in the retentions of heavy metals such as Cu, Cr, Cd, Ni, Pb, Zn, Al and Fe, and by doing so, the quality of runoff water was considerable improved. They are also capable to improve the quality of the runoff water, when they are compared with conventional roofs, Green Roofs can reduce the concentration of lead by a factor of 3, cadmium by a factor of 2.5, copper by a factor of 3 and zinc by a factor of 1.5 (Kosareo, 2007), but it is important to make more research about the elements and arrangements that allow these levels of reduction.

2.3.3 Regulating Services.

Heat Island Effect.

Urban Heat Island Effect (**UHIE**) can be understood as the effect of the accumulation of energy (might be in the surface or the air) in urban areas compared to surrounding suburban and exurban areas, which might occur due the incapability of energy reflection, and therefore the accumulation in building and pavement. The ecological transformation of areas into urban centers, disrupts the natural procedures of energy and matter exchange, this disruption of the balance promotes the acceleration or inhibition of certain processes, which increases the risk and inability to action from extreme events.

UHIE is becoming a noticeable effect in many big cities around the world because the increase of temperature can reach on average up to 6ºC (Jauregui and Luyando, 1998), and in some places where the disruption of equilibrium is higher, and the establishment of infrastructure accelerates this phenomenon, the temperature can reach differences up to 10º C (Balinas 2013).

Considering the United Nations forecast, by 2050 more than 70% of the global population will be living in urban centers, and the global population would exceed 9 billion people, it is relevant to analyze and understand these issues which represent an increasing pressure on the proper allocation and use of resources, for instance, it has been estimated that the levels electricity consumption can be found to be double and triple for the cooling of buildings (WMO, 2013).

The incorporation of **UA** can be seen as a potential mitigation measure, the transpiration process allows the release of water vapor into the atmosphere, reducing the temperature by the transformation from sensible to latent heat. According to United Nations Environmental Program, the construction and maintenance of buildings account for about 40% of the global primary energy requirement, and buildings account for 33% of the global greenhouse gas emissions (Dutil, 2011), therefore, the incorporation of synergies is essential to maximize de efficient use of resources and reduce the impacts of urbanization.

Several studies have analyzed the benefits of the incorporation of **UA** as a regulation strategy in urban centers, and the results are attracting more and more stakeholders for the incorporation in the future. In cases where cities with a high demographic levels, continuously issues regard to the access to land, therefore, the association of **UA** in building conforms an important opportunity for mitigation. Analysis of the potential cooling effects with the incorporation of green areas in buildings (for several purposes) have provided savings between 1-15% of annual consumption (Wong *et al*, 2003), furthermore, they are proven to increase the albedo of urban areas which is usually on values of 0.1-0.2 for graved surfaces to 0.7-.85 (Berardi *et al*, 2014). Some other studies argue that a reduction of 10 ºF in densely populated cities can be achieved by the integration of green roofs on 50-60% of the buildings (Luckett, 2009).

The number of studies regarding the energy efficiency and the mitigation capacity of events such as **UHIE** is increasing, the analysis on the variety of species and the synergies that can be associated are relevant for the future transformation of urban centers if the principles of sustainability and adaptation for climate change continue within the global agenda.

Storm Water Attenuation.

Urbanization process involves the transformation of the natural habitat and the physical dynamics involved such as hydrological, biochemical, and nutrient cycles. On the local level, severely transformed urban centers can be considered as highly vulnerable to extreme climate events due the progressive loss of the attenuation capacity. The incorporation of **UA** has the potential to reduce the negative effects associated with the disruption of the hydrological cycles, it is able to increase the infiltration rate on unpaved areas, reduce the amounts of run-off water that are increasing every year in urban centers, and improve the quality of that water.

Climate change is modifying the periodicity and severity of weather events in all the world, many cities are starting to adopt nature-based solutions (which may include **UA** and Green Infrastructure) to mitigate these effects, such is the case of Portland, Singapore, Sponge Cities, Colombo and Augustenborg (Soz, 2016).

These mitigation measures can take form of bioswales, green roofs, planter box, rain gardens, rainwater harvesting, permeable pavements, mangroves, and wetlands.

In general terms, Green Roofs can be considerable as the most suitable strategy for every urban center regarding floods issues, this due the accessibility of unused space, and the results that have been achieved during the last decades. Some studies have showed that the runoff mitigation can reach 60-100% which depends on the kind of arrangement installed for the Green Roofs (DeNardo *et al*, 2005, Van Woer *et al*, 2005).

Studies made by Mickovski (2013), compared the runoff levels for 3 vegetation varieties (long grass, Sedum, and short grass) and obtained that higher levels of runoff reduction were possible with the long grass (**Figure 7**), which provides an important relevance towards the definition of suitability of plants.

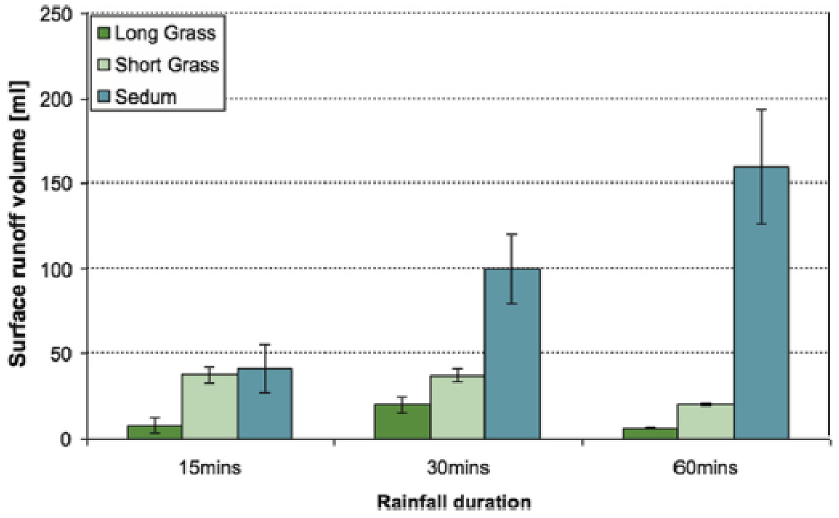

Figure 7. Comparison of the water run off rates between species (Mickovski, 2013).

The potential benefits for the incorporation of **UA** and Green Infrastructure Technologies can take form on a wide variety of sectors, nevertheless, it requires a holistic understanding of the interconnectivity of variables, and the possible external effects that feedback the system. It is essential to go deeper in the incorporation, and analysis of nature-based solution in order to reduce the high vulnerability levels that urban centers are currently facing and achieve resilience.

Air Quality.

Air pollution has become one of the biggest challenges of urban centers in the XXI century, the accelerated process of urbanization has dramatically promoted the disruption on the natural regulator capacity, and nowadays it is important to identify the relations and dynamics in order to and mitigate these issues. Following the estimations of the United Nations Framework Convention on Climate Change, more than two thirds of the world energy are currently being consumed in urban centers, which represents about 70% of global CO2 emissions, and most of the emissions come by the burn of fossil fuels, which is representing a health issue in many of places, where the number of private vehicles is on the rise due a deficit on infrastructure for public transportation, and most importantly a lack of policies for many of the industries that contribute with the largest amount of emission.

Urban transformation is fundamental if sustainability is meant to be reached, and the adoption of **UA** could provide the guidance to a holistic approach to adapt and mitigate the impacts, plants are able to consume pollutants gasses through their stomata and by doing so also modifying the microclimate condition of the place, some estimations point out that even 37% of common pollutants (SO2, NOx and PM10) could be reduced by extensively adopting these nature-based solutions (Tan and Sya, 2005).

2.3.4 Cultural services.

Ethical Values and Education.

UA can be understood as a multiple dimension strategy to be adopted in cities. Among many of the benefits that might be obtained, it is also important to be recognized as mechanism of empowerment for the society though an increase on the collaboration, and participation for the common good. Providing spaces and resources for the implementation of agriculture in urban centers can be understood as an educational strategy for the population that it is interested to collaborate democratically for a sustainable and more fair future for the citizens.

Several studies have found that people who have the access to collaborate in community gardens are more likely to increase their fruit and vegetable intake (Snyder *et al*, 2016). **UA** participation can also provide multiple social capital benefits in term of norms, networks, and trust that is built in a community.

2.4 Where can it be found.

2.4.1 Community Gardens.

Defined as “gardens, green areas and parks, created and operated jointly, and through voluntary engagement with the focus on public access (Rosol, 2006). They are usually unused spaces provided by the government to increase the green space within urban centers., they are intended to recover the ecological structure that has been modified through rapid urbanization process, at the same time they are mechanism to enhance local food production for vulnerable social groups.

2.4.2 International or intercultural gardens.

Differ from community centers for migrants primarily by the fact that people work with each other, that they have soil as a common basis on which they produce essential goods like fruits, vegetables, but also friendships (Muller, 1992). Food becomes a deliberative democracy tool for empowering endangered and excluded communities through participation.

2.4.3 Company gardens.

This approach intends to build resilience among urban centers where the downstream of economic fluxes occur, it aims to mitigate the effects of the rapid urbanization rates, and the effects of certain industrial activities. The main purpose is the creation of green spaces for commercial or recreative purposes, but social integration is not necessarily addressed.

2.4.4 Self-harvest.

This kind of **UA** that occurs through the cooperation of consumers with farms, by acquiring the access to land (rather or not paying a fee). This could be related to the principle of usufruct, giving the access to the society to get involved and at the same time gaining additional income.

2.4.5 Community Supported Agriculture.

Is a community-based cooperation between farmers and consumers, where the farmers have the commitment to provide quality and quantity of food to meet the needs of the consumers. On the other hand, consumers are required to provide support to farmers and get involved with the issues that may emerge.

2.5 Urban agriculture practices.

2.5.1 Horticulture.

Usually characterized by intensive production systems of vegetables and fruits, which is the most common practice that takes place on all continents. Urban horticulture includes a variety of crops that are generally perishable, high value, including culinary and medicinal herbs. These multifunctional systems are candidates to improve the biodiversity in urban centers, providing refugee for pollinizers and providing ecosystem services. This kind of farming can take place in a variety of forms and levels of investment, for small-scale, it usually makes use of containers where the access to land is limited, nevertheless, the outcomes can be optimized and maximized with other practices such as hydroponics where the amount of soil required is minimum and the use of water is less.

2.5.2 Hydroponics.

The concept of hydroponics can be defined as the technique for growing a certain variety of fruits and vegetables in the absence of soil and making use of a natural or artificial substate that provides mechanical support. Hydroponic systems are characterized for the constant recirculation of a nutritive solution on the roots of the plants, which provides all the required nutriments for their proper growth. One of the most relevant aspects of hydroponics is the high yields that can be obtained and the amounts of water that can be saved compared to conventional agriculture.

Hydroponics might sound as a contemporary technology in the field of agriculture, but it dates to several hundreds of years. The dominant records usually mentioned on the literature comes from one of The Seven Wonder of the Ancient World, the Hanging Gardens of Babylon, the gardens were able to flourish making use of an elaborate watering system that supplied a steady stream of river water rich in oxygen and minerals (Folds, 2018). More recently evidence shows how the Aztec Culture in Mesoamerican adapted an ingenious polyculture system referred as “Chinampas” based on the same principles.

Jan van Helmont experiments in 1600, are recognized as the first recorded scientific approach which aimed to discover how plants obtain substances from the water. Following to his results, several studies were developed for centuries to determine the parameters and conditions that allowed the proper growth of plants. It was not until 1930, when the scholar from the University of California W.F. Gericke mounted an experiment laboratory and the term hydroponics was acquired (Resh, 1995). Based on his experiments, it was possible to stablish a systematic approach on how food production might be developed making use of a nutrient solution, and the partially absence of soil, in a way that could be economically profitable and technologically feasible, but at the same time, that could only be possible with a high requirement of capital and energy for its maintenance.

It has been estimated that each hectare of recirculating hydroponics greenhouse has the potential to replace 10 hectares of rural land and save 75000 tons of fresh water per year (Caplow, 2009). Therefore, the future incorporation of alternatives that increase the feasibility and sustainability of the system are highly relevant.

2.5.3 Aquaponics.

Aquaponics is and integrated multi-trophic system that combines elements of recirculating aquaculture and aquaponics (Goddek *et al*, 2015), it consists of a 2-stage system that aims to create a symbiosis between the plants, which are on the higher level, and some varieties of fish on the lower level. A major aspect about aquaponics is the feasibility to maximize the use of nutrients (on the contrary to hydroponics) through the periodical exchange of enriched water from the fish to the fresh water of the plants (**Figure 8**), which provides the feasibility for the establishment of synergies between fish, plants, and bacteria. There is currently a big debate about the possibility for the expansion on these systems, however, the analysis for enhancement strategies remains due the complexity and the energy requirements for their maintenance.

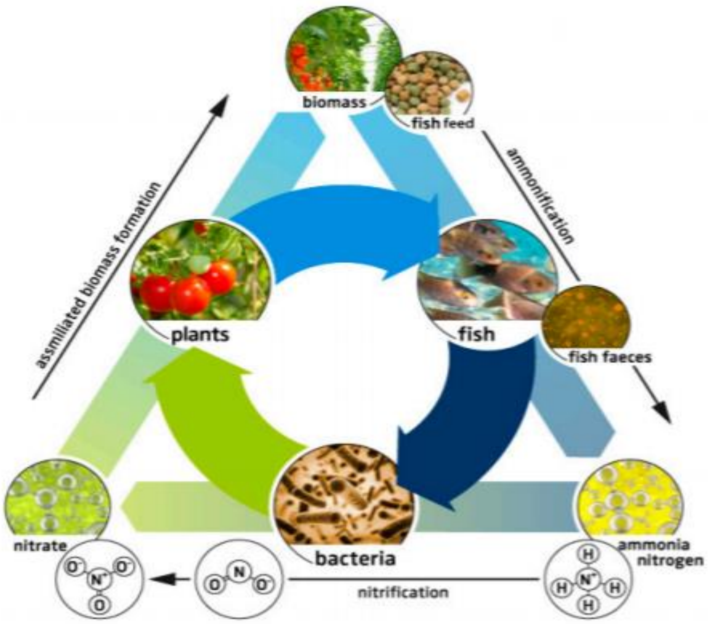

Figure 8. Linkages within the aquaponic system (Goddek et al, 2015).

Meanwhile it has not been largely adopted because of the cost effectiveness of the system, however, this practice is promising and could become an alternative that could contribute in the future to urban sustainability (by maximizing the use of resources), and food security. Furthermore, aquaculture has the capacity to increase biodiversity or diminish it, to enhance the urban environment or harm it. Instead of a mechanical-chemical-polluting sanitation process, beneficial aquaculture can convert a substantial portion of a city's wastewater (and some of its solid waste as well) into food, greenery, and biodiversity (Smit, 2001).

2.5.4 Rooftops.

The emerging growth of urban centers on 20 and 21st century has increased the pressure and the difficulties to access to land, therefore, one of the main issues regarding the debate of **UA** refers to the accessibility. The process of urbanization continues to grow mainly in developing countries due the several factors, one of the main relevant is the dispossession of land in rural areas, and the stagnation of sources of job through the mechanization and industrialization in agriculture.

Being able to allocate spaces efficiently in cities is one of the relevant topics for stakeholders in the 21st century, which should be able to guarantee for the healthiness of their citizens. Nonetheless, the use of roofs is mainly misused and could become a revolutionary strategy of cities, that could provide a wide variety of ecosystem services such as mentioned before. It has been estimated that roofs may cover up to 32% of cities, and due their properties they qualify as potential spaces for nature-based adaptation systems (Frazer, 2005).

The adoption of this strategy is gaining relevance mainly in countries of the Global North, such is the case of the Germany, USA, Japan, and Canada., since they are being represented as one of the most effective adaptation strategies in urban centers towards climate change. The increasingly interest in their adaptation in urban centers has been arising mainly due several studies of the potential to the reduction of energy in building, the curb of pollution, the mitigation of run-off water, the reduction of heat island effect, the increase in biodiversity, and the capability to be adopted as food production areas to contribute to food security (Weider, 2018, Berndtsson, 2010).

Green Roofs can be classified according to its purpose, use, and demands as intensive and extensive. Intensive Green Roofs are characterized by having a thick substrate layer that may vary from 20 to 200 cm, and therefore they are able to shelter a wide variety of species, this kind of roof is high capital cost, and the structural requirements are higher due the weight of the systems, they also require high levels of maintenance, water, and resources. Contrary, Extensive Green Roofs have a substrate layer that usually never surpasses 15 cm, which reduces the variety of species to be adopted but at the same time requires a lower capital investment, and the structure requirements are lower. They need minor maintenance, water, and resources. These characteristics make possible to adopt few varieties of vegetation types such as grasses, moss, and few succulents.

However, they both are both characterized by its basic elements such as vegetation layer, a substrate or growing layer (adequate for a proper retention of water), a filter layer, a drainage layer (which allows to extract the excess of water) and finally a waterproof layer (which protects the roof from infiltration). **Figure 9** provides a schematic reference of the conventional arrangement among the different layers.

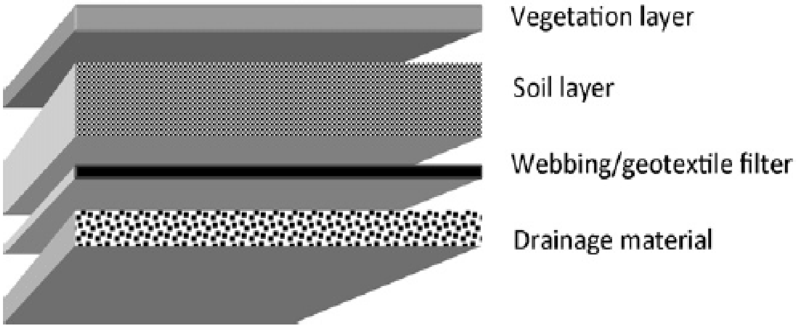

Figure 9. Typical configuration of a Green Roof (Berndtsson, 2010).

2.6 Urban Agriculture types.

For the purpose of this study, the taxonomy developed by Goldstein (2016) was adopted with the aim the stablish a hierarchic order depending on the number of elements considered for every system.

2.6.1 Ground-based-non-conditioned systems (GBNC).

GBNC systems, are characterized for the minimum number of resources that are required such as external energy and matter inputs., a high labor demand is necessary and that is why these kinds of systems are usually run by non-profit purposes and emerge from social participation, such is the case of many community gardens around the world.

Therefore, they are usually considered to provide lower yields compared to high capital and energy inputs such is the case of greenhouse farming systems. On the other hand, this might result in a lower carbon footprint compared to traditional systems (Smit, 2001) since they provide a medium to high symbiosis potential for the assimilation of a wide variety of resources such as wastewater, food waste for composting, and use of recycled materials.

One example of **GBNC** is the case of Detroit Michigan in the United Stated, which due the liberalization policies adopted by Ronald Reagan in the decade of the 80`s, a large number of corporations relocated their production to countries that provided cheap labor and easier access to resources. This transformation had a massive impact in Detroit, where the main economic source of income of the population came from the manufacturing industry. From a population of 1.8 million people, nowadays is around 800 million people, a vast proportion of land was abandoned, and the highly marginated population saw the opportunity to start growing food., easy access to open land, fertile soil, and proximity to water made feasible the extension of these systems, and today there are over 1400 farms and community gardens that contribute to the food security of the citizens (Colasanti et al, 2012).

2.6.2 Ground-based-conditioned systems (GBC).

GBC systems are identified for the higher levels on the use of technology which optimize and maximize the yields of production. The energy and capital requirements are proportionally higher than **GBNC**, since they usually require structural, mechanical, and operational components (sensors and computers). They can be also classified in passive systems, when they rely on environmental sources of energy and water (insulation and rain capture), and active systems, when additional amounts of light and heat are required for the maintenance of the system, which are obtained from fuels or electricity, therefore, the carbon footprint differs widely according to the location and the arrangement adopted.

The symbiosis potential might be reduced since these systems rely mainly in hydroponic technics, nevertheless, the possibility to incorporate synergies such as substrate obtained from treated waste, use of treated wastewater, and use of nature-based nutrient solutions is gaining relevance, and in the future is expected to get access to strategies that promotes the synergies and circularity of the production process.

One example of these systems is the emerging Greenhouse farming sector in the Netherlands, which since commitments to increase the farming outputs were made by the National Government 2 decades ago. Nowadays, Netherlands has become the second world food exporter by value with almost 50% of their land being use for agriculture. They also have the highest yields reported in the world, with a production of 144,352 tons per square mile, the total water footprint is almost 14 times lower compared to the US, and 23 times lower compared to the world average (Viviano, 2017). These achievements have been possible by the incorporation of highly controlled Greenhouse farming systems that allows one of the highest yields of production by having a strict control of all the variables involved in the production. One of the future challenges for the Netherlands is to develop strategies that allow synergies to maximize the use of resources and minimize the amounts of energy required for maintenance, and by doing so, being able to achieve sustainability in terms of carbon footprint.

2.6.3 Building-integrated-non-conditioned systems (BINC).

For **BINC**, the efficiency in the consumption of water and nutrients are similar for the **GBNC** systems, although, they usually require high levels of capital that restrict them to run for profit purposes. For some cases the water consumption can be optimized by the adoption of certain practices such as hydroponics. On general terms these systems are considered as high erosion vulnerable due the conditions on the site such as the weather. Nevertheless, there is a high symbiosis potential in terms of organic waste and wastewater assimilation, increasing on the albedo effect, storm water attenuation, and by the insulation of the building which can result in the reduction of the electricity consumption as previously mentioned. It is essential to identify the purposes for the system as they are design-dependent, and a deep understanding on the variables are required to maximize those benefits, just is the case of the variety of species, phenology, substrate, infrastructure of the building, and the capital requirements.

As example for these systems, is the adoption and transformation of roofs that Mexico City stakeholders in collaboration with FAO and the Ministry of Agriculture of Cuba have promoted since the year 2007, with the establishment of the Program Technology Transfer of Small Scale Sustainable Agriculture, which among the objectives are the contribution to food security for vulnerable people, the mitigation of **UHIE**, the improvement on air quality of the city, reduction of runoff water, and the promotion to the access to green areas to the general population. Nowadays, it is estimated that more than 22000 square meters of green roofs have been created within the city (Dielman, 2017) and the adoption of available spaces such as roofs is getting relevance when the access to ground level land is difficult.

2.6.4 Building-integrated-conditioned systems (BIC).

The operational conditions of **BIC** are very similar to the **GBC** systems, most of these systems are characterized for having the highest capital requirements since they are usually operated for profit purposes. Most of the systems make use of a wide variety of hydroponic and aeroponic arrangement and they usually have the higher yields than non-conditioned systems, on average 25 kg/m2 for integrated and around 13-14 kg/m2 for non-conditioned systems (Goldstein, 2016). Potential for synergies is limited but it is a topic with an increasing interest on research., most suitable synergies can be achieved by the optimization of heat within the building and the roof, the assimilation of organic waste for the formulation of nutritious substrates for hydroponics, and by the reduction on energy consumption by external passive sources (Nowak, 2004).

An example for this, is the case of “Lufa Farms”, which in 2011 was the first company to establish the world’s first commercial rooftop greenhouse in the city of Montreal, with an approximated area of 31,000 square meters, adopted for the production of a wide variety of vegetables and herbs. Nowadays, they have extended their production to an area of almost 168,000 square meters, that provide thousands of food baskets for the urban dwellers. Those systems are characterized for the extensive use of vertical and horizontal growing systems, and they have created synergies within their building the reduce the energy consumption by 50% (compared to conventional systems), transforming and adopting food waste into compost, and saving water making use of highly efficient irrigation systems and water harvesting.

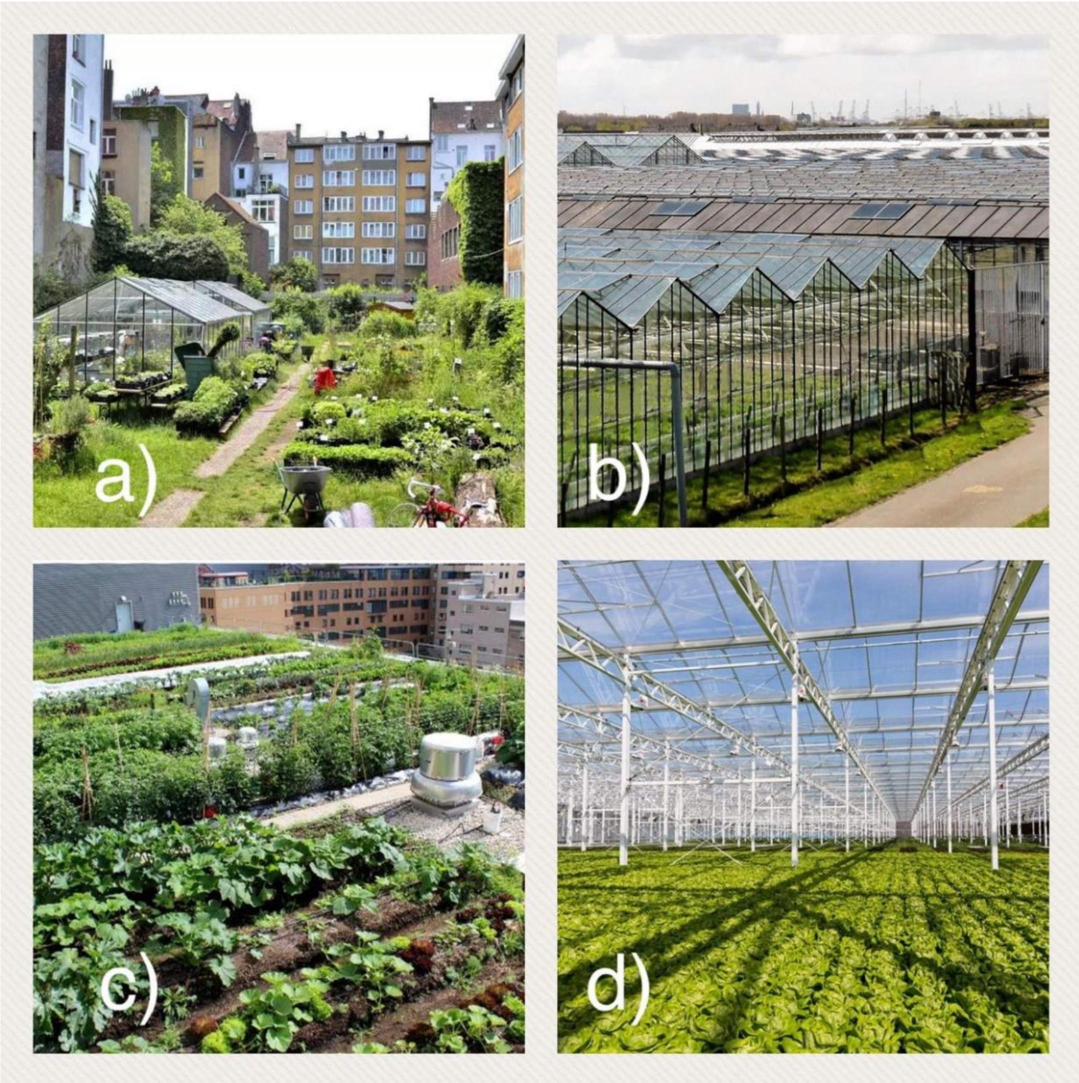

Figure 10. Taxonomy for Green Roof Systems, a) GBNC, b) GBC, c) BINC, d) BIC.

2.7 Trends and Challenges.

With the growth of urban centers, the challenge to fulfill sustainability is getting wider and more complex. The amounts of energy and matter to maintain them are increasing every year and the resulting waste cannot always be assimilated by the surrounded systems. In places with no access to effective infrastructure such as public transport, sewer systems, waste facilities and effective policies, health issues are rising on a rapid rate.

The levels of poverty and inequality continue rising mostly in the global south (Hickel, 2017), therefore strategies such as UA can become a resilient mechanism towards sustainability, although, there is skepticism about the positive and negatives impacts involved in these practices in terms of a) marginality, b) safeness, c) inefficiently and d) unsustainability.

There is a critic about **UA** being a marginal activity and its capacities to contribute to food security, nevertheless, it has been documented how urban UA improve the food security and levels of nutrition's of low-income families. UA which considers the production in peri-urban areas contributes with a significant proportion of food consumed in urban centers such is the case of Mexico City, Hanoi, Jakarta among many others (Dieleman, 2017). At the same time generate income and jobs. This emerging sector provides economic opportunities for small-scale entrepreneurs and large corporations to enhance the practices and spurring local economy.

It is argued that UA is not safe due the input sources, the levels of pollution, and the health risk associated. It is true that bad practices in the reuse of waste, the amount of pollution in soil and water, and the use of certain products can represent a thread, but it all comes in how the practices are implemented. Urban farming has the potential to improve the hygiene in the city and sustainable ways due the effective capacity on transformation of waste.

The inefficiency of UA critics relies on the assumptions of the high proportion of land required and the cost it may represent in urban centers. Here is where the concept of usufructs becomes relevant, UA employs land unused of unsuitable for other purposes and many cities possess large proportion of this unused land.

Effective policies are required to break through this paradigm and transform gray spaces into green and edible.

Discussion about how sustainable UA might be assumed to emerge from the pollution of soil, water, and air where these practices take place. An effective transformation process requires guidance and assistance to tackle these issues, when good practices are acquired the gains overcome the losses. Sustainable farming reduces air pollution, soil erosion, modifies microclimate, crates connectivity among green areas and provides a sensible way to dispose solid and liquid waste.

The potential of UA is largely undervalued for many stakeholders, although it is a rising phenomenon that involves and promotes social participation, and it can be acquired as an essential tool in urban centers to face their issues towards sustainability.

2.8 Describing the area of study: The metropolitan area of San Luis Potosí.

The Metropolitan Area of San Luis Potosí (**MASLP**), is an urban conglomerate conformed by the cities of San Luis Potosí, Soledad de Graciano Sanchez and some other cities, delegations, and communities around the area, such as Cerro de San Pedro, Mexquitic de Carmona, La Pila, Escalerillas, etc.

According to the latest estimations made by INEGI (2018), the actual population of the metropolis increased from 1,040,443 in 2010 to 1,133,571 inhabitants by the year 2017. It is located in a semi-arid region in the central part of the country with a surface of 23599.28 ha, and it is expected to continue growing to 25338 ha by 2025. The area has an average annual temperature of 17 °C, with an altitude of 1877 meters above the sea level. The average annual precipitation is 350 mm, and most of this takes place from June to September, at the same time, due the high rates of radiation, the global annual evapotranspiration potential varies from 1950 to 2250 mm according to the proximity of the mountain systems.

Starting in the 1990´s with the signing of the Free Trade Agreement (MX-USA-CND), the state of San Luis Potosí started a deep transformation on the social, economic, and political arrangement that had prevailed for the vast majority of the century. The aperture of the markets along with the geographical relevance of the area because of the proximity to potential markets, created an attractive environment for the establishment of large industries. A rapid process of migration from rural to urban areas started to take place, local farmers were facing big threads and were not able to compete with the large, subsidized agroindustry's, and in many cases forced to leave their land in order to subsist (Del Valle, 2016). It has been estimated that the farming area declined deeply from having a surface of 20,196 ha in 1991, to a surface of 6682 ha (SAGARPA, 2017).

This transformation as described by Moreno-Mata (2018), can be described in 3 mainly stages; a) The concentration stage which is characterized by the centralization of the population from rural to urban areas (1950-1980), b) Dispersion, which occurred by the resurgence of new urban centers in the surrounding areas (1980-2000), and c) Fragmentation of the area due the economic and political transformation.

Therefore, the absence of strategies, planning frameworks, and institutional coordination, for the vast majority of the cities in Mexico that have followed the industrialization path (such as the MASLP), have created a process of urban expansion which tends to occur horizontally and disordered, causing issues relevant issued for the mobility, access to services, pollution and social segregation (UN, 2012).

The rapid process of urbanization has altered deeply the resilience of the urban system, increasing the vulnerability of certain groups of the population to floods, increasing the levels of pollution for the lack of planning on transportation systems, accelerating the social fragmentation and social segregation that the inequalities exacerbate, and transform the lifestyle of the population in terms of consumption, promoting the access to fast food, with a very high caloric contribution and low nutrient value, which at the same time becomes an important issue for the increasing levels of diet related diseases.

This pattern becomes clearer when estimations about the levels of obesity point out that 70% of the population in Mexico is overweight, and the rates of chronic diseases are becoming a national epidemic (Reynoso *et al*, 2007). During the

COVID-19 pandemic period of 2020-2021, more than 200,000 people died, and it has been estimated that a large proportion of these people acquired some chronic disease associated to their lifestyle and consumption patterns (Sosa *et al*, 2020).

Meanwhile a constant economic growth has taken place, and San Luis Potosí provides an important contribution to it for the industrial and mining relevance, the levels of poverty and inequality have prevailed and are expected to grow with the effects of the COVID-19 pandemic. On the national scale, Mexico has been ranked among the 25% most unequal countries in the world (Campos-Vázquez *et al*, 2014). Following this path, between 2016 and 2018, the Gini coefficient grew from 0.45 to 0.464 which represent an increase of 3.2% on the levels of inequality. According to the latest estimations of the National Council for the Evaluation of the Politics in Social Development (CONEVAL, 2020), on the state level, 50.8% of the population which amount to 1,437,900 people has an income below the poverty line, and 43.4% of the population (1,229,000) lives under poverty. At the same time, 480,000 people does not have a full access to food, 747,800 people lacks the access to basic living services, 479,500 people face educational lags, and 253,600 people does not have access to health services.

Regarding the food and health issues that the MASLP is currently facing, the access to green spaces points out to be relevant and must be addressed if strategies to increase the urban resilience and health of the population are aimed to be implemented, however, in terms of green spaces, spatial inequalities can be observed. Studies point out that 85.9% of the total population in the MASLP, did not have a proper access to public green space, only about 16.5% of the total green space (Mata and Lara, 2016).

According to World Health Organization (WHO), every city should guarantee an accessible, sabe and functional minimum of 9 square meters of urban green space for each person, nonetheless, for this vast majority of population the number remains below 6 square meters.

Chapter 3

Urban Agriculture Potential: The Metabolism Analysis of San Luis Potosí.

Chapter 3. Urban Agriculture Potential: The Metabolism Analysis of San Luis Potosí.

3.1. Understanding urban metabolism.

Industrial revolution gave the proper mechanisms for the dramatic expansion of urban centers, being able to allocate more resources by the incorporation of a wide source of elements for the transformation of energy, that allowed the increase of size, density, and finally complexity around the world. On the global scale, it has been estimated that urban settlements occupy nearly 2% of the world land surface, however, they consume over three-quarters of the world resources, and discharge similar amount of waste to the environment (Swilling and Hajer, 2017).

Therefore, being able to understand the mechanisms that allow the proper function of urban cities has gained relevance since the nineteen century, it has been stated that in order to guarantee and maximize the proper allocation and use of resources, identification of all the embedded relations (economic, social and politic), and their implication in the fluxes of energy and matter had to be acknowledge as a mean to guarantee an adequate functioning of the system.

The awareness on the implication and the effects that urban centers perform on the surrounding environments made necessary to develop mechanism to model the functioning of these systems, which allowed the recognition of the most relevant aspects and the most suitable intervention points, therefore, by the second half of the nineteen century, the idea of metabolism was firstly adopted as metaphor for the explanation of all the process involved and since then and following the evolution on the complexity of urban centers (Fischer-Kowalski,1998), metabolism has become and iterative approach that constantly evolves and incorporates more and more elements.

Karl Marx who was influenced by the German chemist Justus von Liebig, was the first who adopted the term with the purpose to describe the interdependent relationships and the material exchanges between human society and nature. His argument referred about how the capitalist societies have accelerated the expansion and transformation of urban centers, and by doing so alienating society from their natural condition (Foster, 2011), on the same way, this approach guided about the implications that had to be considered if urban centers are aimed to be analyzed and modelled properly.

During the twentieth century, the first application of the concept of urban metabolism was made by the American engineer Abel Wolman (1965), who provided the first hypothetical model of a city and the elements that integrate it, with the purpose to identify, understand and explain the balance of the systems, quantify the inputs, transformation and output that are involved in in a city, and by doing so, be able to provide a plausible intervention strategy.

In terms of usefulness, urban metabolism is able to provide and overarching approach to understand the most relevant drivers of a systems and their possible interactions among each other, it provides an scheme to understand and measure the resource demand and the pressures on the surrounding ecosystems that these generate, the feasibility and the flaws of the systems with respect of the proper allocation of resources and with that providing the capacity for the establishment of interventions and solutions for these issues.

Nevertheless, there is a big debate on how urban metabolism fails to provide information about the health of system, it does not provide information about the properties and structural elements such as social and political factors, becomes challenging due the deficits on data for the proper analysis, and requires a multilateral cooperation (which might become an obstacle) with more disciplines to incorporate missing aspects in order to avoid bias.

Having said that we can conclude that the definition of this concept should become as an iterative process that evolves through time according to the increase on the level of components that are associated and incorporated, nevertheless, for the purpose of this work, some definitions are presented with the purpose to stablish a theoretical framework and the procedural sequence for this chapter.

Urban metabolism can be defined as the sum of material and energy produced or imported, as well as waste produced by a city to support its daily activities (Kennedy *et al*. 2008). Urban metabolism can be understood as a way of enhancing or understanding of the way in which, environmental, social, and economic factors interact to shape urban phenomena and processes (Rapport, 2011).

There are currently several disciplines and approaches for the analysis of urban metabolism in terms of the intention and the elements that are aimed to be measured, these disciplines are: a) Urban Ecology, b) Industrial Ecology, c) Ecological Economics, and d) Political Ecology.

For Urban Ecology, the city is understood as an ecosystem in the biological sense of interaction between organs, that demand, consume and excrete resources, cities are embedded in a larger system and depend deeply on the external inputs for their maintenance and subsistence. Analysis of human-environment relations makes possible to understand and interpretate effectively urban centers in all of their complexity (Broto et al, 2012), this analysis would provide the mechanisms to shift from a linear to a circular approach that maximizes the allocation and use of resources. Nonetheless, this might result in the conflating of concepts, the limitation of the analysis and fostering misleading interpretation due the oversimplification.

Industrial Ecology made a big reference on the complex system theory with the purpose to identify the dynamics, entities, and the feedbacks that happen on the system in order to measure and quantify the material and energy flows and by doing so making cities less dependent of their wider hinterlands (Dinarès, 2014). Their approach is similar to Urban Ecologist in the sense that, recording and quantification make possible to describe the relationship between the environment and the urban system but not in an interconnected and interdependent relationship. Although, several scholars argue that the flaws of this approach rely on the large among of elements, and flows that cannot be quantified, but make part of the social, economic, and political dimension (Carpintero, 2005, Newell and Joshua, 2015).

For the Ecological Economics, there is a big difference on how the dynamics of the systems are associated to the economic sectors and laws, the economy is arranged from a low entropy raw materials and energy into a high entropy waste and unavailable energy system (Daly and Farley, 2004). Their notion and goal for the urban metabolism aims to guarantee the material basis for the economy, identify the economic drivers that allow the maintenance and the sustainability of the system for the future, with the focus of economic growth and resource consumption. Some of their current debates towards climate change, go into the direction of the steady state economy (carrying capacity) and de-growth theory (referred to the use of resource along with the growth of the economies).

Political Ecology among with the economical approach aims to identify the structural flaws of the systems that create the unequal distribution roles and failures for the proper allocation of resources. They tend to wide up the analysis on a large scale to identify what are the conditions occurring on the outside that create the structural inequalities and conflicts on the inside (Hornborg, 1998). Quantification of economic and materials fluxes allows to identify the accumulation disparities and segregation process which at the same time, makes evident the necessity to establish intervention mechanism in terms of policies.

Therefore, the analysis of complex systems such is the case of urban centers, should be addressed for the consideration of the different dimensions that could be involved in the study of a particular element of the system. Being able to identify the level of interaction among the agents is relevant at the moment of applying interventions, and the multiplicity of possible feedbacks should be evaluated on each one of the dimensions.

3.2 Methodology.

Having the purpose to estimate the potential integration of UA in the metropolitan area of San Luis Potosí, this chapter would make a review on some previous findings about the urban metabolism and would provide an alternative approach on how some of the elements identified in those studies could be reincorporated into the system by the integration of UA practices. Therefore, following the Benavides (2016) approach, the food dimension was explored by analyzing the flows of water, energy, and matter, as well as the distribution of surface and land that could be incorporated for the implementation of UA alternatives capable to provide climate change adaptation and food security improvement.

Based on the overall system, it was possible to collect information about the availability and management of resources for the MASLP (input-transformation-output) on the large scale, and that information served as a reference for the surface analysis and the possible introduction of UA. The analysis of the urban metabolism consisted on the quantification of a complex system model for the MASLP (**Figure 11**), that provides an overall estimation of the number of interaction and elements that take place within the system.

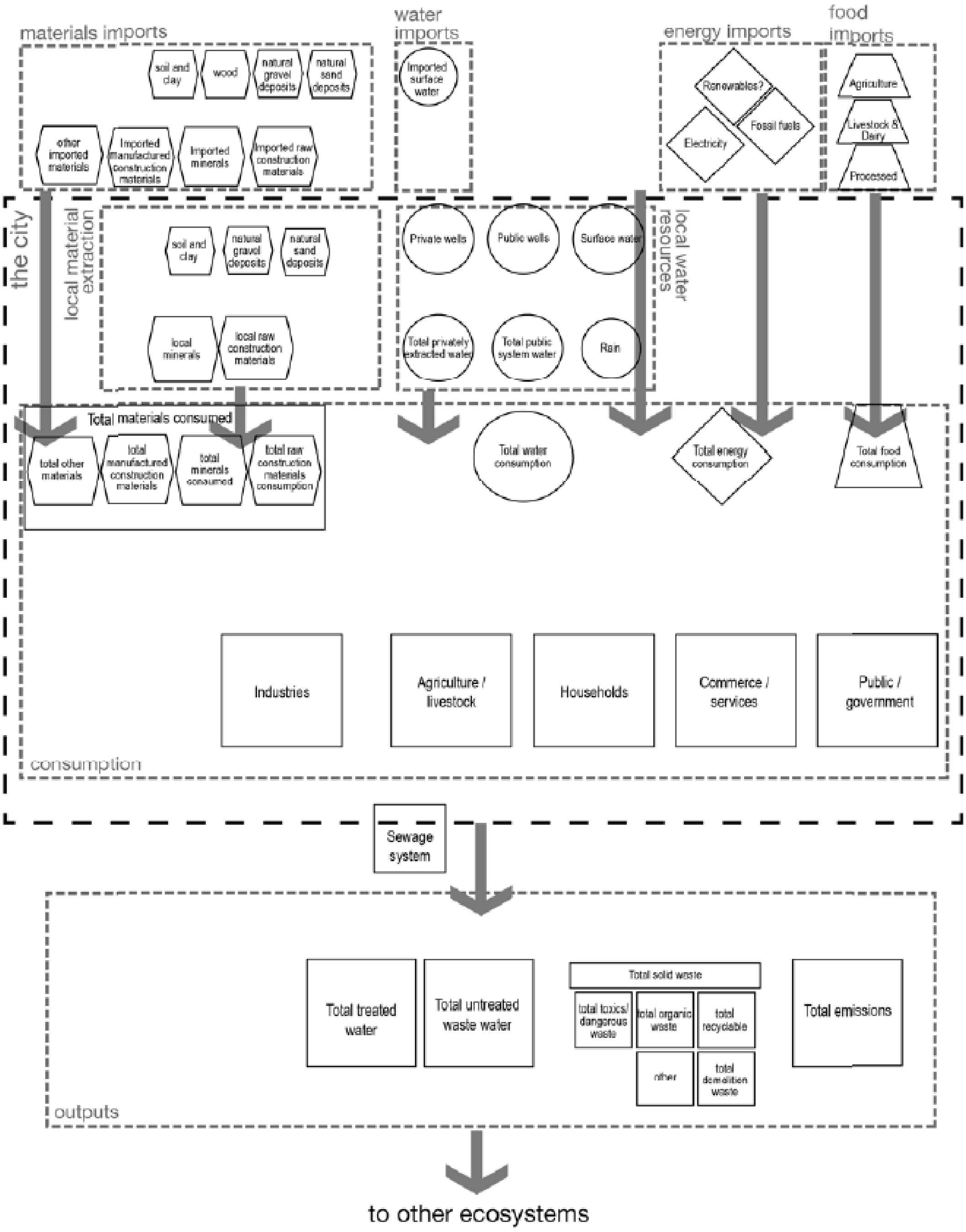

Figure 11. Urban Metabolism of MASLP (Benavides, 2017).

Additionally, an estimation of the total roof surface in the MASLP was performed to provide a reference of the possibility for **UA** integration. For the surface measurement a supervised classification was performed making use of Satellite high resolution images from Sentinel 2, and the software “ArcGis” version 10.2. The satellite image was obtained on Earth Explorer portal from the United States Geological Survey (https://earthexplorer.usgs.gov/). The image used is a composition from the bands 2, 4, 5 and 8 (**Table 1**).

Number of bands	Name of the band	Central Value of the band length (nm)	Spatial resolution (m)
2	Blue	496.6	10
3	Green	560	10
4	Red	664.5	10
8	NIR	835.1	10

Table 1. Criterion used for the supervised classification.

Following this, an evaluation of the accuracy for the classified imaged was performed making use of 53 points of reference where only 4 points did not correspond to the classification. The percentage of accuracy was obtained by making us of the next equation, and a value of 92.453% of accuracy was calculated.

$$\%\ of\ accurary = \frac{Number\ of\ points\ of\ reference\ classified\ correctly}{Total\ number\ of\ point\ of\ reference} * 100$$

Once the roof and land surface for the MASLP was obtained, a classification was performed according to the type of land use, established by the Urban

Development Program and Population Centre of San Luis Potosí (IMPLAN, 2021), and the Strategic Population Centre Plan for San Luis Potosí- Soledad de Graciano Sánchez (IMPLAN, 2003). This classification was established with the intention to determine the overall image of the building and their structural characteristics.

The types of land use are the following:

- Residential. Are classified in 3 mainly densities (High, medium, low), the biggest proportion of the city is classified within the low density which is characterized by small area houses and a high level of proximity among them, likewise, most of the apartment buildings and family units are classified under this category.
- Equipment. This category is conformed by building that provide services such as universities, shopping centers, supermarkets, hospitals, etc.
- Industry. As the name mentions, building under that category are conformed by industrial warehouses stablished mainly in the Industrial Zone of the Metropolitan Area.
- Historical Center. Within this polygon determined in both programs of urban development, the oldest buildings of the city are located, and are also regulated by special policies and institutions such as National Institute of Anthropology and History (INAH).
- Suburban. In this category, human settlement that are under the transition from rural to urban can be found.

Furthermore, an introductory metabolism analysis, and an estimation of the total roof area (due the inaccessibility of land) in the UASLP western campus was conducted to determine the feasibility for incorporation of urban agriculture on rooftops. The surface estimation was possible with use of the digitalized architectural plans and the software “AutoCAD 2018” on the version 22.

3.3 Results

3.3.1 Water and Food Security Nexus.

The MASLP, is characterized for the rising levels of industrialization that have prevailed during the last 3 decades, which have transformed and accelerated the process of urbanization. The area has become an economic pillar for the manufacturing industry due their geographic relevance and the economic incentives that allows large investment for multinational corporations, therefore, from being a relevant place for agriculture production, nowadays, performs as one of the main industrial centers on the national level. For the purpose and limitations of this study, the energy dimension was excluded from the analysis.

3.3.2 Water input, consumption, and output.

Regarding the water dimension, the water supply system on the national level is centralized and it is operated by the Water National Commission (CONAGUA), which is in charge for the management on the quantity and quality of water within the country, therefore, it is the institution in charge of providing the national policies and programs that guarantee the most efficient use the resource and it´s maintenance for the future. Nevertheless, it is operated on the state level in all the country by institutions which are in charge for the formulation and tracing of the policies and the programs, monitoring the efficient use and discharge, the extraction, and the protection of the resource, either it is surface or groundwater.

The institution in charge for the state of San Luis Potosi is the State Commission of Water or **CEA** for their initials, they are responsible for the management for the extraction, distribution, and discharges of water according to the types of use and requirements for the economic and social sector. The MASLP, relies strongly on the groundwater extraction for the provision of services and in minor proportion on surface water such is the case of dams. According to the national regulations, water extraction operates by public ally operated wells and dams (between 74%-54%), and the emission of concessions for the private sector (between 26%-46%).

The rapid process of urbanization that has taken place as previously mentioned, has altered the recharge areas of the area to the point that runoff water has become an important risk for large sector of the population (Moreno-Mata et al, 2019).

According to Interapas (2015), 95 million m^3 of ground water are annually extracted, however, since there is a discrepancy due the unaccountability of the wells and dams privately operated, it has been argued that around 144 million m^3 are annually extracted (Benavides, 2017).

Some estimations point out that runoff water from rain amounts 33.7 million m3 (Interapas, 2015), which is a higher proportion than the water imported from the dam “El realito”, which is one of the main surface sources of water for the city. It has been pointed out by Santa Cruz de León and Eguía del Pozo (2016), that the whole domestic demand could be covered with less than 20% of the rainfall if the proper mechanisms and infrastructure is adopted.

In terms of water consumption, as reported by the Water rights public registry (REPDA), there are 87 federal concessions to industrial users that amounts nearly 11.3 million m^3. One of the main issues that the metropolitan area faces is the tremendous amounts of water that gets lost by leaks on the distribution system, it has been estimated that this amount it is nearly close to the amount of water extracted from the aquifer that provides service to industrial and agricultural uses (Benavides, 2017).

Regarding the water outputs for the **MASLP**, in 2016, Interapas documented that the total wastewater produced was 51.2 million m^3, meanwhile, on those reports non-treated water accounted for almost 25 million m^3., having a total of 76.5 million m^3. However, this information varies largely between the municipal institution and the institution on the state level, where additional amounts are considered and the total output accounts for 90.3 million m^3.

3.3.4 Food inputs, consumption, and output.

There is currently low interest for the municipalities in the **MASLP** for the quantification of food that comes from the surrounding areas, the majority of reports made by SEDARH, point out mainly about the productivity in gross numbers, although, since the food supply has been centralized there is no accessible information about the dynamics and fluxes that occur between the urban and rural areas. According to Benavides (2017), not a single institution is currently working for the quantification of the food supply system in terms of consumption, and the most relevant information records comes from the state economy secretary (SEDECO) and the municipal commerce department, who perform and inventory of the total of facilities in the MASLP that distribute fruits and vegetables (711 in total). One first approximation could be made by taking the national fruit and vegetable consumption average (which is 47.5 kg/year) to provide and overall estimation about the requirement of the food system, nonetheless, it provides no relevant information about the patterns and dynamics that take place on the allocation of resources.

3.3.5 Estimating the potential for the incorporation of UA.

As previously mentioned, UA can become an important mechanism for mitigation and adaptation to the effects that come along during the urbanization., for the case of the MASLP, where the levels of runoff water and leakages are constantly increasing, where the levels of food insecurity and the centralization of the food systems continue to grow and where strategies for climate change are required, **UA** can be introduced as a multidimensional strategy that can create the opportunity to mitigate and alleviate a large number of issues in terms of Water-Food-Energy, nevertheless, since the demographical expansion has occurred largely horizontally, the incorporation and adaptation of roofs in the MASLP, might result as the most plausible opportunity, although, the rehabilitation and incorporation of the current green areas could also provide potential benefits.

Therefore, according to the methodology described, an estimation of the total roof and green areas surface for the **MASLP** was performed (**Figure 12**), in order to identify the potential areas for adaptation and incorporation of UA.

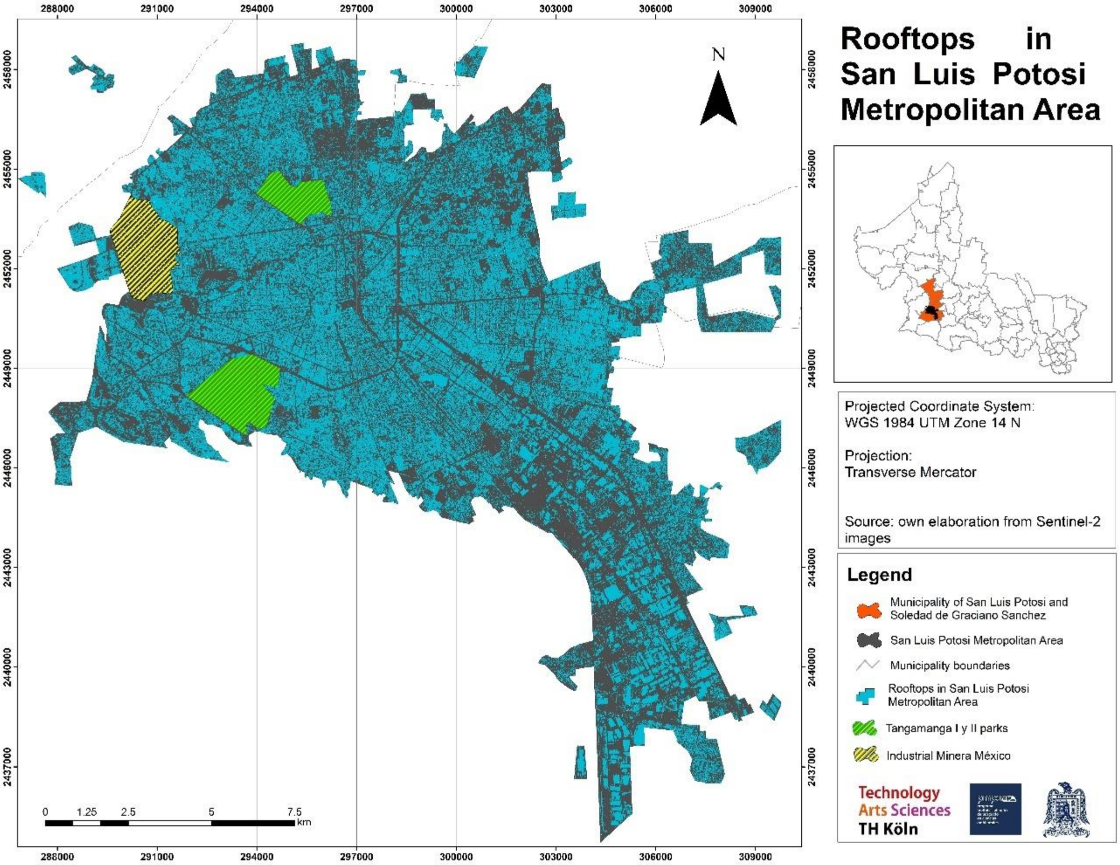

Figure 12. Rooftop distribution in the MASLP.

Based on this first approximation and with the intention to estimate an adequate proportion of roofs with the technical and structural capability for the transformation into green roofs for food production, another classification was performed according to the type of land use (**Figure 13**).

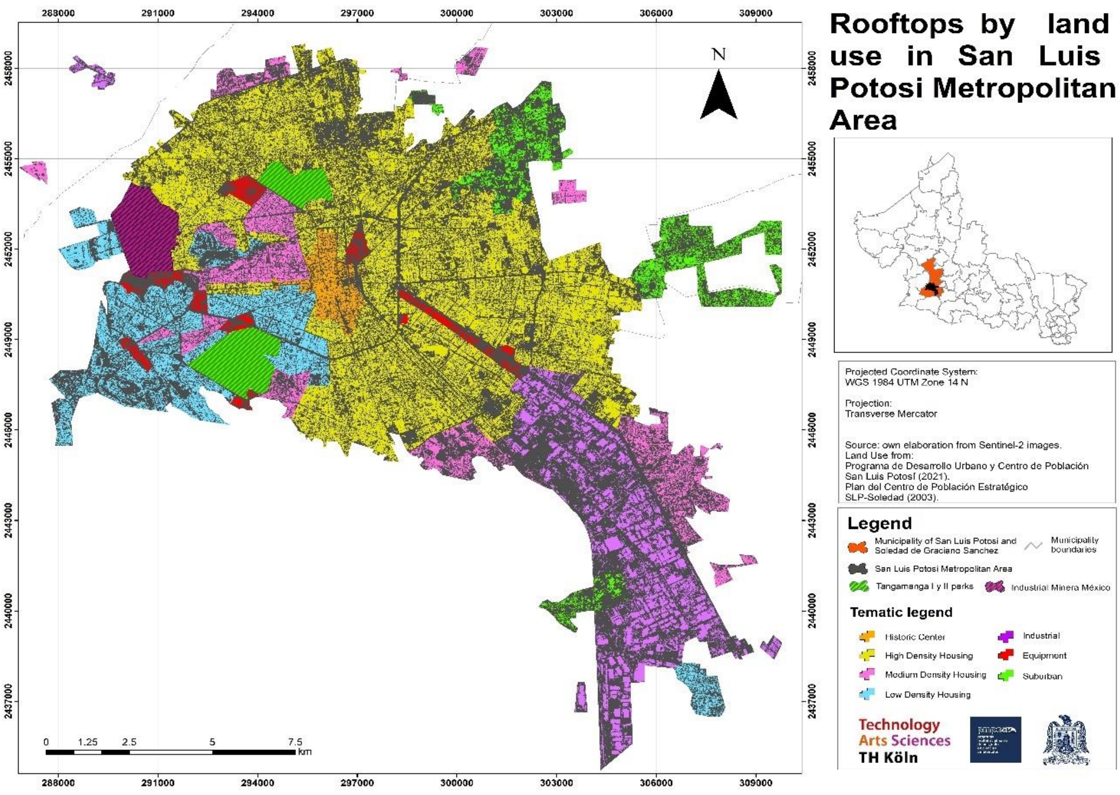

Figure 13. Rooftop distribution in the MASLP according to the land use.

The total surface area was calculated making use of this classification and the results can be found on **Table 2**.

Type of land use.	Surface area (m^2)
Residential Low Density	13,115,806.10
Residential Medium Density	10,955,087.74
Residential High Density	50,705,540.20
Equipment	2,214,457.99
Industrial	12,384,541.56
Historical Center	2,432,916.37
Suburban	6,070,522.45

Table 2. Surface area according to the type of land of use in the MASLP.

3.4 The metabolism of Autonomous University of San Luis Potosí.

For the purpose of this study, the western campus of the Autonomous University of San Luis Potosí will be used as an exemplification of the metabolism approach (on the relevant terms for the implementation of UA), therefore, an analysis of the system would be introduced and would be sequenced by the policy and guideline recommendation on the following chapters.

The population within the west campus of the Autonomous University of San Luis Potosi has constantly grow during the last decade, which has created the demand for new spaces, and a higher demand for resources. According to the records made by UASLP, in 2019, the number of people involved in this campus (from student, collaborators, professors, and staff) account for 14,119, which are divided in each one of the faculties (**Figure 14**). One of the strategies that is it currently gaining relevance for the promotion of sustainable development and enhancement of food security, is the formulation of education models that allow capacity building among all the sector of the society, which as previously mentioned can be promoted by the use and extension of **UA**.

Figure 14. Spatial distribution of UASLP western campus.

3.4.1 Water and Food Security Nexus in UASLP western campus.

The west campus of UASLP show some deficiencies in the use of energy and water within their facilities. By instance, access to water is possible by a well water that is in the campus, nearly 24 L/s are extracted every day (2073 m^3/day), from which 3 L/s are channeled for the use in the Campus (3 m^3/day), and the rest goes to supply the municipal system and the nearest health facility called "Hospital Central. Currently UASLP west campus consumes 6.5 L/s for all their purposes, and the difference comes from the municipal water supply (Rueda, 2004). However, there are possible intervention strategies that could be adopted in order to efficiently maximize the use of this resource. By instance, according to Picos (2010), an important contribution to reduce the water consumption and achieve self-sufficiency could be achieve the following interventions: a) substitution of the sanitary facilities (reducing by 23% the consumption of water), b) the implementation of water harvesting technics (which would reduce by 24% the levels used on garden irrigation), c) adopting technologies for water treatment and recycle of gray water (which would provide a reduction on the 77% of water).

Regarding the access to food within the campus and the nearest areas, it is important to mention that there are currently no estimations about the consumption requirements for the population on the west campus. Some approximations could be made by establishing a correlation of the number of hours and the intake requirements. However, this analysis could be approached in terms of the socioeconomic conditions of the university community, and in terms of the food security dimensions (availability, access, utilization, and stability).

Being said that the purpose of this section, is to analyze the potential adaptation of areas for **UA** as a mechanism for enhancement of food security and mitigation of climate change, an analysis of the distribution of green areas and roofs and an estimation of the potential surface for food productions purposes was performed.

The western campus of **UASLP**, currently has 15% of green areas, however, not all the surface remains in good condition, and even some of them have scarce vegetable cover. The current distribution of green area is presented below:

Faculty	Green area (m2)	% green area
Stomatology	3,019	2.3
Nursery	107	0.08
Engineering	6,662	5.1
Chemical Sciences	6,836	5.2
Library	132	0.1
Sciences	1,395	1
Habitat	901	0.6
Total	19,052	15

Table 3. Total distribution of green spaces un UASLP western campus.

Although, in relevance with the total area and the population in the campus, there is a deficit in the proportion of green space because the campus only provides 2.3 m^2/person, which is proportionally low compared to the recommended proportion by the World Health Organization (9 m^2/person). Some proposals for the expansion of green areas in the campus have been made so far, however, because of the infrastructural arrangement and the current allocation of areas, the transformation of surface into green spaces becomes a limitation.

Therefore, some other alternatives must be pursued, and such is the case of green roofs, which can also be introduced as a multidisciplinary strategy that promotes resilience in urban centers, contributes to food security enhancement, promotion/preservation of biodiversity, and education for sustainability. The first approach was made in 2013 by the project called “UniHuerto” which sought to promote the transformation of available areas into green spaces and food production areas within the west campus.

Following the calculation for the **MASLP**, an approximation of the total surface in the wester campus was performed with the purpose to identify the potential roof area and the criteria for their transformation for **UA**. Making use of the architectural plans of the west campus and the software AutoCAD, it was found that across the campus, the total surface of the roof available which remains unused accounts for 446600 m^2, which is distributed in the different faculties of the university. Nonetheless, it is important to define the elements for defining the proper spaces for the transformation of areas and selection of suitable spaces.

Among the element to be considered, which would be discussed on the following chapters, are the following.

- Structural conditions.
- Slope.
- Insolation.
- Accessibility.
- Access to water and energy.
- Access to materials.
- Labor Requirements.

Chapter 4

Chapter 4. Food Policy Analysis.

4.1 Introduction.

The capability to understand a food supply system requires a holistic analysis of the element that are embedded and feedback the system. However, in order to provide interventions on these systems in a manner that can be measured and evaluated, it is essential the formulation of policies. A policy can be defined as a course of actions adopted by governments to introduce certain changes in the decision and behavior of actors that conform society, to achieve certain goals through time (Sadler and Verheem, 1996).

In terms of food dimension, food policy ideals form down to an iterative process of problem definition, consultation, design, drafting, policy approval, implementation, and enforcement., must promote active participation of actor and stakeholders to be able to tackle social, economic, and environmental relevant issues.

They consist of the actions and inactions by government that influence the supply, quality, price, production, distribution, and consumption of food (Birkland, 2005). According to his approach, food policy should include the following elements:

1. Formulation process. Carry on with a clear description of how the process is going to evolve and what actors are pretended to be involved.
2. Concise analysis. Having a holistic analysis of the problematics and the current situation of the food systems such as constrains, opportunities, potentials, positive and negative impacts that might be embedded.
3. Vision. A well stablished vision regarding the desired changes that aim to be produces and how can that be associated with national and local development strategies such as SDG´s.
4. Objectives. Well defined (with quantified targets for the expected results in a certain time), target groups and beneficiaries.
5. Instruments. A proper selection of selection of policies and strategies that may be used to fulfill the objectives.

6. Institutional Framework. A well defines framework and sources of financing for the operationalization, implementation, and monitoring of the policy.
7. Operational Planning. An effective strategy for planning and implementation of measures.
8. Review. A periodic process of analysis and adaptation enhanced with social participation **(Figure 15**).

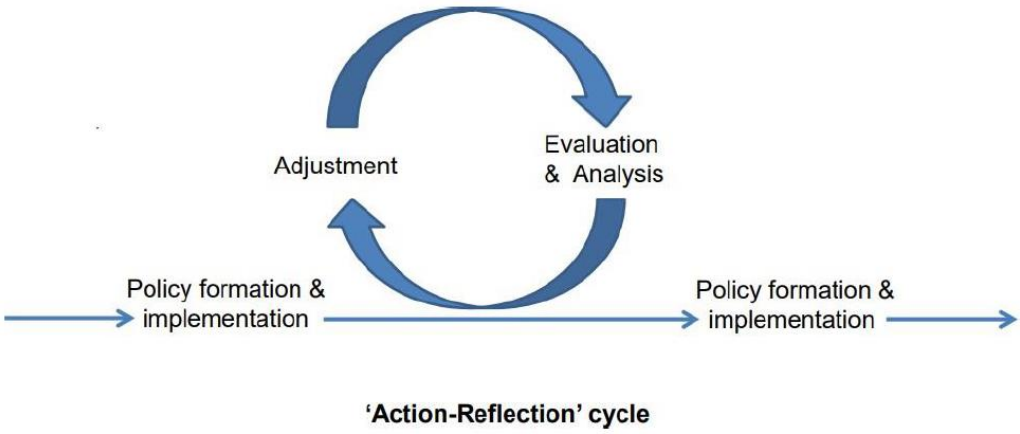

Figure 15. Policy making process (Saadler and Verheem, 1996).

4.2 Methodology.

In order to understand the dynamics of the food system it is essential to identify the most relevant elements that might influence it. For the purposes of this study, the "Milan Urban Food Policy Pact and Monitoring Framework" (**MUFPPMF**) was used as a methodological reference that would allow a wider understanding of the food system, this framework is a tool developed recently, during Expo 2015 in the city of Milan by representative of many city mayors around the world, with the purpose to stablish a methodology to assess the current status of food chain systems and by doing so, achieve the capacity to develop sustainable and resilient food systems, that guarantee nutrition's and accessible food to all, protect biodiversity and fight against food waste (FAO, 2018).

The framework is articulated in a set of 37 recommended action and 44 indicators organized around six categories: 1) governance, 2) Sustainable diets and nutrition, 3) Social and economic equity, 4) Food production (including urban-rural linkages, 5) Food supply and distribution and 6) Food waste. **Figure 16** narrows the connectivity between actions, indicators, and categories.

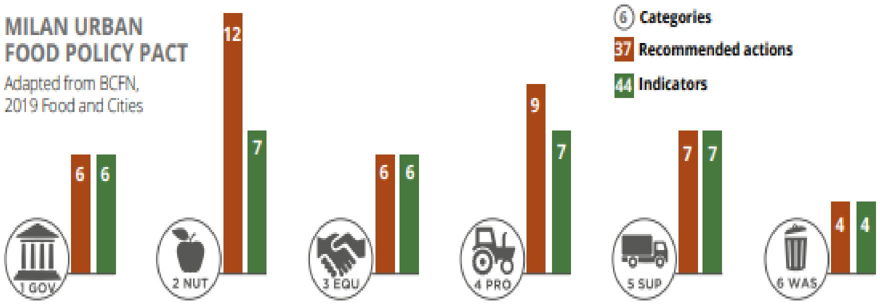

Figure 16. Relation between outcome areas, indicators, and recommended actions.

Based on these elements, the MUFPP may serve as an instrument for cities and urban food stakeholders to identify food-related policy and program priorities. The current analysis of a system using this framework can provide the most relevant data, that may work as leverage points to create intervention strategies in order to improve food security and reduce pressure on the ecosystem by reaching sustainable production systems.

MUFPPMF, has been designed to serve as an instrument for cities to identify food related policy and recognize priorities, provides an inclusive narrative that supports municipal governments through the designing of food policies, projects and investments providing information on indicators, methodologies, application, and constructs that may be relevant to consider regarding food policy decision process.

Recommended actions that are provided by the framework serves as an example of how governments can approach to their issues and meet the desired outcomes; they are built on the direct experience of policies, programs, and projects that government apply and that are considerable relevant. They provide an entry point, although all the proposal must be adapted to the local context.

Indicators provide information about the process transformation of food policies and systems; their purpose is to measure the extent to which the desired changes are happening. They provide a baseline from which to measure ongoing progress or change. The 44 indicators that the framework provide can be organized as self-assessment when the measure is the presence and absence of a specific policy and as quantitative when it is possible to measure absolute numbers such as costs, consumption, income, proportions, etc.

Therefore, an operationalization analysis was performed for the MASLP to identify the main drivers that are interconnected and influence the food system. As well, the construction of a story line according to the outcome areas was created. With the purpose to improve the analysis strategy and involve different perspectives non based on indicators. Interviews with different actors involved in any stage of the food supply system were performed during the months of April and June. Their experience and understanding on the issues of the food systems made possible to extend the amount of information for the cases where the information was unavailable or hard to obtain (such is the case of a large number of indicators from the **MUFPPMF**). Based on this, the following section provide an exploratory narrative of the most relevant aspects that were found during the analysis in each one of the outcome areas of the framework.

4.3 Results.

4.3.1 Governance.

The first outcome of the **MUFPPMF**, points out about the relevance of capable institutions and stakeholders that are involved with each one of the sectors that conform the food supply systems, and provide the guidance and the mechanisms to guarantee the effectiveness and resilience of the supply and maintenance of the population. On the same line, about the importance of having entities for the promotion of practices that increase the social participation and decentralization of the food system and by doing so, reducing the vulnerabilities for the population at most risk.

As previously discussed, the food system has fallen into a process of centralization during the last 3 decades, a large number of small farmers who constituted the base of the food supply system in the past, have been dragged to the abandonment of their land and activities due the absence of mechanisms that allowed the access to resources for the maintenance of the land. All along the political speech during these years, it has been noticed about the relevance and the contribution of these farmers due their contribution to food security and prevalence of the ecosystem services that they promote by agroecology practices, nonetheless, at the same time the expansion of large, subsidized industries that promote the technician approach (in terms of inputs and outputs instead of a systemic analysis) has occurred.

For the case of **MASLP**, there are currently no municipal interdepartmental government body in charge for the formulation of policies and programs (through the active participation of actors involved), actions addressed to the regulation and transformation of the food systems come mainly by the intervention of centralized institutions (such is the case of Secretary of Agriculture, Secretary of Commerce or Secretary of Health) and by the forces that feedback the system (either internal or external) from the private sector. Efforts to promote the multilateral cooperation among the actors involved in the food systems have been marginal, according to the research, for the State of San Luis Potosí, only once an initiative for this took place in the decade of 2000 by a system called "Producto SLP", which was stablished as a mechanisms to encourage the cooperation within the food supply (from production, consumption, processing, distribution, and waste recycling), by the creation of committees that would provide the space for integration, communication and coordination to harmonize the production with consumption, increase the welfare of everyone involved, boost regional and technological development, and guarantee the quality and safeness. Nonetheless, right after the formulation, few actions to preserve this participatory approach were made by the absence of regulatory and faciliatory entity, therefore, no further contributions were made and the system was practically dissolved, which have made that the collaborations across sectors become marginal for the following years.

One of the issues from the point of governance that was noticed across the interviews performed with some of the actors of the food supply system is the inability of actions from local institutions, this lack of recognition and unavailability to act has exacerbated the incapacity for multilateral cooperation across the relevant representatives and stakeholders, which tend to take unilateral actions. The vast majority of policies addressed to promote and regulate the food supply system come from the national level and are usually transitory, furthermore, lack of context and understanding of the structural issues is something that has prevailed, which can be observed through the centralization and dismantlement of the traditional food system.

Enhancement of participation and political cooperation is relevant if the food supply systems are intended to become inclusive, fair, sustainable, and resilient., the formulation of appropriate and contextualized policies can provide effective and decentralized solutions, although, the mechanisms for share of knowledge have to be created and monitored to allow and promote the best practices, and the proper allocation of resources.

4.3.2 Sustainable Diets and nutrition.

The sustainable diets and nutrition outcome area refers to the analysis of the elements that conforms the actions related to the health status of the population on the municipal scale, the importance of this outcome area is evident because it provides an overall picture of how the food requirements of the population are fulfill, and how is that related to criteria's such as diversity, accessibility, and frequency. For the case of the **MASLP**, it has been stated how the urbanization process has transformed the traditional diets, and promoted the access to high caloric and low nutritional food, which has provided the stage for the deteriorated health status of the population. This situation has come along with the increase of the food prices that has prevailed since the economic crisis in 2008 (Gilbert, 2010), to the point where the levels of obesity and diet related diseases have grown exponentially.

According to the data collected by CONEVAL, which is the institution in charge of the measurement of poverty in Mexico (among some other responsibilities), the price of a nutritious food basket which is one of the basic criterions for the analysis, has rose significantly from $977.92 in 2010 to $1730.85 pesos in 2021 for urban areas, and from $692.64 in 2010 to $1245.71 pesos in 2021 for rural areas. On the same direction, the minimum wage in Mexico has been stagnated since the beginning of the century, to the point where food security fails to be provided for the large number of the population. Some studies refer about how the low levels of income are associated with the transformation of consumption patterns from traditional diets to industrialized food that is easy, fast, and affordable., nevertheless, with very low nutritional content and high caloric rate (Guerra *et al*, 2006, Vega-Macedo *et al*, 2014).

According to the National Survey of Health and Nutrition (ENSANUT, 2018), 8.6 million people have been diagnosed with diabetes, which represents 10.3% of the total population, 11.4% of the total are women and 9.1% are man. Based on these numbers and estimation made by the Health Secretary of San Luis Potosí, around 197 thousand people have been diagnosed with diabetes, and some other studies point out that the number might be higher because of the disease nature and the inaccessibility to health services for the proper diagnosis.

Few studies have been made for the case of the **MASLP** to determine about the relevance of food deserts and food swamps, food deserts refers to an area with limited access to affordable and nutritious food, meanwhile, food swamps refers to an area where there is an abundance of fast food (Fielding and Simon, 2011), however, it can be pointed about that the vast increase on diet related diseases of the society Mexico is associated with the alteration of consumption patterns due the large availability of cheap food with high-calorie/lo-nutrient rate.

Given this deterioration on health condition of population in Mexico, the Secretary of Health is constantly formulating new programs that promote healthier lifestyles and increase awareness about the negative effects of unhealthy diets. At the time of this study, there are currently 25 operating health programs addressed mainly to the prevention and control of diabetes, nutrition and physical activity, and the promotion of breast feeding. Within the activities of these programs, are the participation and collaboration in forums in schools, hospitals, and private institutions, to promote the consumption of nutritious and diversified food, and address the consumption of sugar, salt, and fat.

In terms of policies, actions are being made to regulate the consumption of unhealthy-high caloric food., in February 2021, a modification to the article 75 of the General Education Law was performed, which stablish that the education authorities should promote the prohibition of sale for food with low nutrimental value and high caloric content on educational facilities. On the same direction, on October 2020, the Official Mexican Norm 51 (NOM-051) came into force, which establish that prepackaged food should include warning labels according the levels of sugar, fat, and salt., meanwhile, the use of animations on packages (which alludes for child consumptions) is forbidden.

The rearrangement on the economic policies that took place since the beginning of 1990, accelerated the urbanization process and the transformation of the consumption patterns in Mexico, meanwhile the centralization of the food supply systems on the national level is moving forward, to the point where the food systems are structured no to satisfy need social needs but to promote profits.

4.3.3 Social and economic equity.

The social and economic equity outcome area aims to analyze the current status of the predominant social and economic structures, as well as the mechanisms that prevail in each one of the urban centers, by making use of the data about the health condition of the inhabitants, the accessibility to assistance programs, the levels of jobs and food security, and by the existence of mechanisms addressing issues for the most vulnerable and marginalized people.

During the last 3 decades, a large number of strategies have been presented for the enhancement of the conditions of the population of Mexico (which the vast majority lives under precarious conditions), however, meanwhile there has been a constant economic growth in the country, these conditions have prevailed for a large number of issues such as the failures and inequities of the system, the inconsistency of the public policies, corruption, lack of monitoring, deficiencies on the coordination across sectors, among several other conditions.

Meanwhile, the levels of poverty and hunger remain on an alarming level, according to ENSANUT (2018), on the national level, 45.5 % of the population live under food insecurity, from this number, 22,6% of the people live under moderate food insecurity, and 32.9% of the people under mild food insecurity. Simultaneously, CONEVAL (2018), reports that 43.4% of the population in Mexico lives in poverty conditions, from which 7.3% lives under extreme poverty, meanwhile, according to the National Institute of Public Health (INSP, 2013), the state of San Luis Potosí is located as the fifth entity in the country with the highest prevalence of food insecurity, where almost 8 out of 10 households are perceived as food insecure. Meanwhile, the levels of inequality have rose constantly on previous years which is more evident on the MASLP due the highest economic relevance. According to estimations from 2019, the income distribution inequality based on Gini coefficient in the state of San Luis Potosí has a value of 0.46 (Statista, 2021), which is very similar to the national average.

In order to improve this condition, the promotion of assistance programs on the national level has prevailed as the main strategy for mitigation, according to CONEVAL (2020), 5174 programs and actions addressed to social development are currently operating, and based on their mapping, the main areas for intervention are the following: a) education, b) health, c) nutrition, d) housing, e) healthy environment, f) social security, and d) inclusion.

Following the report for the Evaluation of Policy on Social Development (2018), a relevant proportion of the income for the population in Mexico that lives under poverty, comes from the transfer of these programs and actions, meanwhile, they have the potential of becoming redistributive strategies for societies with high levels of inequalities, these assistances by themselves cannot guarantee financial security (Esquivel *et al*, 2010).

Additionally, in terms of food assistance, The National System or Integral Family Development (**DIF)** is the institution who promotes many programs for the allocation of resources for marginalized communities in urban and rural areas for the state, meanwhile providing food transfer to these communities, they seek for the intervention and building of capacities for the communities with programs addressed to food production (either vegetables or meat), although, their biggest contribution comes from the assistance on feeding school programs that benefits around 165,000 thousand children in the state, and since the start of the COVID-19, the number of beneficiaries rose by 470,000, at the same time, the total number of beneficiaries of federal assistance programs (either cash or food transfers) reached 540,000 people in the state .

As mentioned, the merely transfer of resources without intervention on the social and economic structures prevails as the main intervention strategy for mitigation and enhancement of food security and poverty, without providing relevant results for the vast majority of the people, therefore, it is essential to enhance the formulation of policies that encourage and support local economies, empowering the population to become driver of change for the decentralization of the food system and the economy. Filling the gap between the disaggregated sector of the society must come by the understanding of the failures, the collaboration across coalitions through enabling the right policies, and the financing to allow the ability to act.

4.3.4 Food production (including urban-rural linkages).

As previously discussed, the accessibility to cheap sources of energy, made possible to allocate in an economically feasible way a larger number of products and services for the urban centers, reducing the importance of synergies with the surrounding areas and increasing the impacts that long supply chains create.

The food production outcome area, aims to provide the methodological tools to analyze these aspects, being able to identify the current synergies and the connectivity among the urban, peri urban and rural areas. In relevance with the sustainable development goals, seeks to promote the importance to the access to green areas for the urban residents, the extension of urban agriculture and sustainable practices related, that can take place within the boundaries of the system, and promoting the participation of residents.

Historically, there has been constantly reduction in the proportion of land dedicated for food production within the MASLP and the surrounding areas, the contribution of food from local producers in the nearest farming areas has also decreased for several reasons such as the effects of droughts, the lack of programs and incentives from the agriculture secretary, and the centralization of the distribution channels from large producers. In an interview performed with some functionaries of the Agricultural Secretary of Development (**SEDARH**) in

San Luis Potosí, they mentioned that since the incentives are very small and the benefits are not enough, a large number of small producers are currently producing in a very low scale only to be able to apply to assistance programs, which was the case of the agricultural insurance which provide monetary compensation for crops damage.

There is awareness about this situation and some efforts are being pushed to promote and enhance the conditions for local farmers in the state of San Luis Potosí in terms of collaboration, adaptation, and training., however, the biggest challenge they mentioned is the lack of coordination across governmental institutions and producers to collaborate together in the implementation of strategies that empower local communities, as well, as the lack of capacity for action from the institution, since most of the programs plans and strategies are centralized and addressed for the implementation on the national level without contextualization.

Within the MASLP, urban agriculture is a concept that it is increasing mainly as a niche market for middle- and high-income sector of the society, who seek to get involved and improve the nutritional quality of their food and become more physically active, however, this remains limited because the access to land and green spaces are limited, and there has been during the urbanization process a segregation of it in terms of income level (**Table 4**).

Sector			Población			Superficie AV			Índice de áreas verdes (m²/hab.)		
No.	Nombre	Superficie (Has.)	Año			Año					
		2010	2000	2010	2025*	2000	2010	2025*	2000	2010	2015*
1	Centro	1625.1	138065	156329	239396	33.4	41.8	41.8	2.4	2.6	1.74
2	Lomas - Tangamanga	1783.0	55080	64215	84555	467.8	503.3	1047.0	84.9	78.3	123.8
3	Morales – Ind. Aviación	1806.2	111318	122604	170888	56.2	79.6	79.6	5.0	6.4	4.6
4	Saucito - Terceras	2234.7	59939	78554	92015	215.3	221.4	221.4	35.9	28.1	24.0
5	Satélite - Progreso	2313.9	207648	213168	290745	14.4	46.7	46.7	0.6	2.1	1.6
6	Zona industrial	2635.6	447	687	1033	0.0	86.4	86.4	0.0	1258.2	836.7
7	Delegación Pozos	3623.5	56711	68295	87058	9.2	38.0	38.0	1.6	5.5	4.3
8	Soledad Norte	1508.1	50268	57183	88845	1.6	16.2	33.4	0.3	2.8	5.8
9	Soledad Sur	1561.0	119309	158785	210866	7.5	29.1	29.1	0.6	1.8	1.3
Total		19091.5	798785	901902	1265055	805.6	1062.8	1623.7**	10.0	11.7	12.8
% AV/Sup.	**2010**	19091.5							**7.0**		
	2000	12859.0								**6.2**	
	2025	27319.1									**5.9**

Table 4. Spatial distribution of green areas in the MASLP (Mata and Lara, 2016).

85.9% of the total inhabitants of the MASLP have access to only 16.5% of the total green areas, meanwhile, 14.1% has access to 83.5% of the total area.

The dominant literature approach for mitigation in urban areas refers mainly about the relevance of green areas due the contribution of ecosystem services, nonetheless, as stated on the MUFPPMF, this approach can be extended by the incorporation of urban agriculture, promoting the mechanisms that allow the usufruct of the land (referring to the right to access and use) within the urban areas, which can become beneficial for the enhancement of the resilience of the urban system, the improvement of food security and the promotion of environmental equity and justice. Few studies have been made to quantify the distribution and contribution from UA within the MASLP due the inaccessibility to data from private sector and lack of interest from governmental institutions in the collection of information, however, studies made by Castañeda (2019), provided a first approximation to geographical distribution of these areas (**Figure 17**), this first approximation was possible in collaboration with pioneers of UA in the private sector who provided some of their contributions.

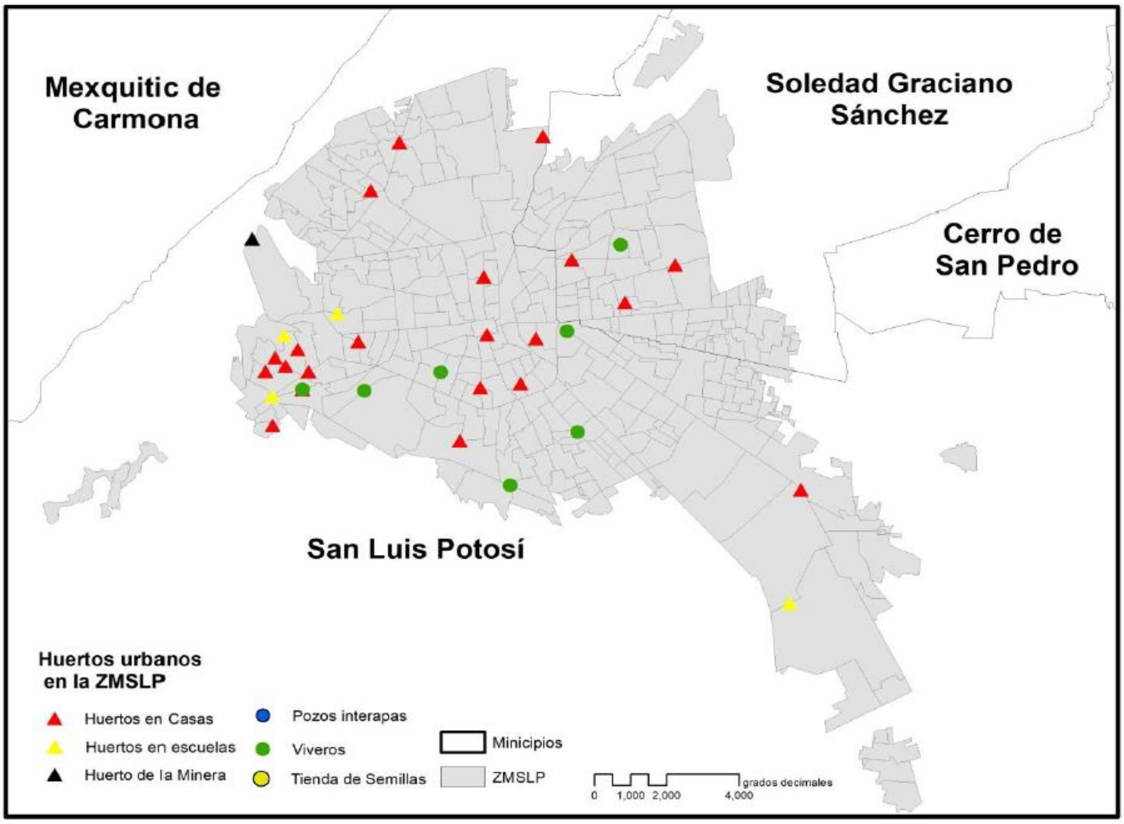

Figure 17. Distribution of UA areas within the MASLP (Castañeda, 2019).

According to her results, UA has been adopted mainly as mechanism to promote education for sustainable development and the consolidation of competencies for the collaborators, however, the contribution for mitigation to climate change and food security was considered marginal due lack of strategies from the municipality, private sector, and civil society.

At the time of the study, there were no policies or incentives from part of the municipalities for the promotion and expansion of these practices, however, by the beginning of 2020 (before the COVID-19 pandemic started), the first law initiative addressed to the expansion and implementation of urban agriculture/farming was presented, in relevance with the strategic objectives of **FAO**, it is intended to create a more inclusive, efficient, and collaborative farming system on the local, national and international level. Following the principles for this initiative, the main objective is to provide for the people who require and request, access to land within the boundaries of the municipality for the expansion of food production by agroecological principles which enhance healthier lifestyles, empowerment, preservation of local species and local participation.

One of the most relevant aspects of this policy initiative, was the compromise for the democratization of land, according it, access to land for food production is stipulated as a right for each one of the citizens in the State of San Luis Potosi, and it was intended that each one of the institutions from the governance sector would provide on their facilities area for this purpose. On the same line, it was required to formulate a legal framework which stablished the principles, requirement, responsibilities, and operational strategies for the implementation on the larger scale. This initiative promotes a multilateral cooperation among different sectors of the public space, from governmental institutions who are in charge for the regulation and implementation of the mechanisms for the expansion, private sector which is persuaded to participate with the creation of economic incentives in order to expand this strategy, the civil society on the promotion for the collaboration and following of the strategies, programs and plans., and finally, the inhabitants who are able to access to a large number of benefits when the guidance and participation of these sector is well stablished.

4.3.5 Food Supply and distribution.

In relevance with the previous chapter, the Food supply and distribution outcome area aims to provide a metabolism approach of the food supply systems (in terms of input-transformation- output) in urban centers, understanding the relevant aspects and feedback mechanisms that take a dominant role on the system, the promotion and enhancement of technologies that enhance the collection of data, likewise, the interventions for the connectivity enhancement between urban, peri urban and rural areas from a social, ecological, and economic inclusive perspective.

The previous chapter made reference about the relevant aspects for the estimation and quantification of food for the MASLP, as well for the patterns, dynamics, and challenges that might be relevant for the future if a proper and deeper understanding of the food system is intended to be achieved. On the other hand, some independent programs to enhance and promote the maintenance of local producers and improve the urban-rural nexus, are being promoted by **SEDARH** and **DIF**, who are operating the programs of small producers which seek to create a network of producers within the **MASLP**, facilitating the mechanisms for their introduction in local markets or collaborating on assistance programs. These efforts and the collaboration of the participants, have allowed the formulation of the Training Center for Self-Production Food (**CECAPA**), located in the Tangamanga Park, which is and initiative that promotes the production of vegetables, fruit, and eggs to support 26 assistance centers. At the same time, they are constantly providing technical support and training for the public who is interested on getting involved on the food system (either on production, processing, distribution, and marketing). Nonetheless, it was unable to quantify despite several attempts to request information to these institutions.

According to interviews performed to local producers, they mentioned that efforts are also being made to facilitate the introduction of their products to the local markets from the private sector, following these, it was mentioned some incentives from large supermarkets (which are normally the dominant distributors of the food supply systems in Mexico) to collaborate, such as the acceleration of the payment process and the easement of protocols for distribution. Nonetheless, this can only be mentioned as an anectodical reference since there was no possibility to get access to information due their privacy policies.

Relevant participation from the civil society addressed to the importance of decentralization of food supply systems and promotion of local producers have come from the Natural and Organic Market Macuilli, which a civil organization that work together with the Autonomous University of San Luis Potosí to facilitate the mechanisms for local producer within the state, to get access to markets and reducing the intermediaries and reducing miles of the conventional food supply chain. This initiative has become the first one on the national level to acquire the competence to provide organic certification for the producers, therefore, according to their principles, facilitation of channels for local producers and the adoption of agroecological practices has the potential to enhance healthier lifestyles (either for consumers and producers), increase awareness for the society involved about the effects of conventional farming systems and unhealthy lifestyles, and increase the preservation of local varieties.

4.3.6 Food waste.

Having already discussed about how urban areas contribute to the effects of climate change in terms of allocation and consumption of resources, this outcome area aims to identify, measure and mitigate the failures of the food supply system in terms of waste., nowadays, where more than 1/3 of the global food is wasted meanwhile more than 780 million people lives under extreme poverty (Melikoglu, 2013), it is essential to come along with strategies that maximize the use of resources and provide interventions for the failure on the system.

On the national level, efforts to mitigate these shortages have come along mainly by the collaboration of the civil society. Nonetheless, estimations about the levels of losses on food have come from the program called "Cruzada Nacional contra el Hambre" which was a national strategy that intended to alleviate hunger, eradicate malnutrition, increase the agricultural yields, reduce losses post-harvesting and increase the participation of communities. Based on their latest data (2018), it has been estimated that on the national level, around 37% of food is currently being wasted in one of the stages of the food supply chain, which amounts for 10 million 431 thousand tons of food every year, which would be enough to avoid hunger for 7.01 million of Mexicans.

Regarding the **MASLP**, nowadays there is an absence of governmental institutions addressing this issue, and it has been approached mainly by the participation of the civil society and non-governmental organizations. There is currently a Nacional Association of Food Banks that works in collaboration with FAO and the Global Food Banking, which has been able to create a national network of food banks that work together for the recovery of food, the building of capacity on the society and the promotion of circularity on the use of resources. Based on and interview performed to one of the biggest recycle food centers in the area (**BAALI**), it was possible to obtain relevant information about the operation, results, and the challenges.

Banco de Alimentos de San Luis Potosí (**BAALI**) is a civil association located in the municipality, who aims to improve and facilitate the access to food for the most vulnerable people in marginalized urban and rural areas. In collaboration with several members of the food supply system (from small producers to large companies), they are able to recover fruit, vegetables, dairy products and groceries before they are wasted, and being able to assist people who lack the basic means for nutrition. They are currently working with more than 70 associations (from schools, nursing homes, orphanages, geriatric centers, etc.), providing food, assistance, and guidance. Empowerment of the society is also one of the elements they seek to promote, providing programs of integral human development that train the participants and promote the building of capacities.

According to their estimations, the **MASLP** waste more than 2 million 520 thousand tons of food per year, and very few efforts have been made to address this issue, at the same time, a vast number of people fails to access a proper and complete nutrition because of the failures on the food supply system. At the moment of this study, there are no policies that remit to these issues, and the tax incentives for the large corporations to avoid these losses are relatively small, therefore, once they reach that limit, it becomes economically unfeasible.

Therefore, they have also been promoting and facilitating political participation from the society to push forward in terms of policies, that regulate these failures and inconsistencies. They have presented to the local congress 2 law initiatives which refer to the promotion of regulation instruments and incentives for the reduction of food waste, and the constitution of a legal framework that stablish the operational procedural clauses for the recovery of food from donors.

From their experience, they mentioned about the lack of interest from the municipality to promote the participation and collaboration from the different actors of the food supply chain, at the same time they remarked about the low continuity on strategies from the local governments (which tend to be transformed every 3-6 year), and how they are unable to structure long time plans, consequently, the vast majority of support comes from the private sector.

During the COVID-19 pandemic, it was evident for them about these flaws and the inequities of the food system, they observed and exponential increase on the number of people who approached the food bank for assistance. Nearly 2000 food baskets were provided daily for the people (which is around 5-6 times more than previous the pandemic), and the number of voluntaries grew to almost 180 people daily, furthermore, a composting area was stablished with the intention to provide it to local farmers, which was only operated until the beginning of 2021 for the lack of resources. By the end of march, they started to see a massive decrease in the number of food baskets required, as well on the collaborating voluntaries, which they associated with the political campaigns that were taking place at the time, that in order to promote the participation, they illegitimately give resources to vulnerable people in exchange of assistance and votes.

Food waste management should be addressed as a mechanisms for the enhancement of food security and mitigation towards climate change instead of a currency exchange of political activity, the absence of regulation on these terms for the **MASLP**, and lack of collaboration across the relevant actors from the food supply systems is one of the big challenges for the future, therefore, commitment, procurement and support has to be allocated, and promoted between institutions, in order to alleviate the situation and overcome the failures of the food supply.

4.4 The Food Policy Laboratory in UASLP campus.

Across the decades, the vast majority of actors that conform the university community of **UASLP**, have advocated and contributed to the creation of mechanisms that promotes welfare, inclusion, ecological preservation, and multilateral cooperation across the sectors of the society. Most recently (from a holistic approach), this has been the case of “Agenda Ambiental”, which is a coordination mechanism that promotes horizontal collaboration between institutions and their departments for the promotion of awareness and actions towards environmental issues.

Among their objectives are the articulation of environmental programs between the faculties, and formalization of institutional support in order to create transcendental impacts trough social knowledge (Nieto Caraveo, 1998). Making use of a participatory approach, they have collaborated with several institutions for the promotion of strategies such as “Agenda 2030” and “SDG”, and based on those experiences they have been able to restructure they action lines in the following: 1) Institutional management, 2) Education and research, 3) Linkage and projects, 4) Communication.

The institutional management action line has been the one that is constantly promoting strategies that involve the effective allocation, management, and preservation of resources (such as water, energy, and food), biodiversity, urban sustainability, and circular economy. In relevance with the direction of this study, a pivotal analysis of the food security in the university community was introduced (based on previous studies) with the purpose to clarify the ongoing condition of the community and the possibility for interventions (in terms of a university policy), to overcome the conditions and the promotion of urban resilience, self-sufficiency and sustainability., having as a reference the basics and principles of the “**MUFPPMF”**.

The previous chapter provided data about the requirements in terms of Water-Food-Energy of **UASLP** western campus, however, it is relevant to amplify the debate and correlate it with the conditions that take place in the community context, be aware about the complexity and the elements that take place in the system, such is the case of the economy, the social conflicts, the current and relevant policies, and the feedback responses from the actors involved.

UASLP is a public university that operates by government funding and accessible fees, nonetheless, they are able to provide some assistance programs and scholarships for highly motivated los income students. The socioeconomic status of the student body is diverse, oscillates between low, medium, and high income. As previously debated, the change of policies on the national level on the previous decades provided the incentive scheme for the transformation of the food system mainly in the urban centers from having a diverse traditional diet to a diet composed by cheap meals rich in calories with low nutrient composition, which has resulted on an epidemic of diet related diseases (Reynoso *et al*, 2007).

There is awareness from part of the institution, about the health challenges under which the university community is involved. This is evident on the Development Institution Plan (PIDE), which encompasses the period from 2013-2023, that points out that in order to promote compliance of the objectives established, a large number of actions (in terms of institutional policies, programs and plans), would be taken to address the relevant health issues that involves the university community, pointing out the urgence for strengthening on health care and promotion of physical activities.

However, according to an extensive study performed by Ayala (2017), who performed and evaluation of the food, physical and health environment within the western campus of UASLP by the selection of a simple random sample across (which is a proper and conventional method to estimate the average behavior on a large group). According to the IMC diagnosis, the analysis found out that 37% of the participants were diagnosed with overweight or obesity, 19.5% of the participants had a high risk to develop some kind of comorbidity, and more than 60% of them were diagnosed with a very low respiratory rate. On the other hand, surveys performed on this study found that 66% of the participants prefer to consume prepared meals (rather they are processed or cooked), and only 20% of the participants mentioned a preference for fruits and vegetables.

In addition to this, an analysis and mapping of the spatial distribution of food expenditures was conducted (**Figure 18**), with the intention to identify the offer of food in the surrounding area of the UASLP western campus and classify it according to their nutritional status (from healthy, low healthy, and unhealthy).

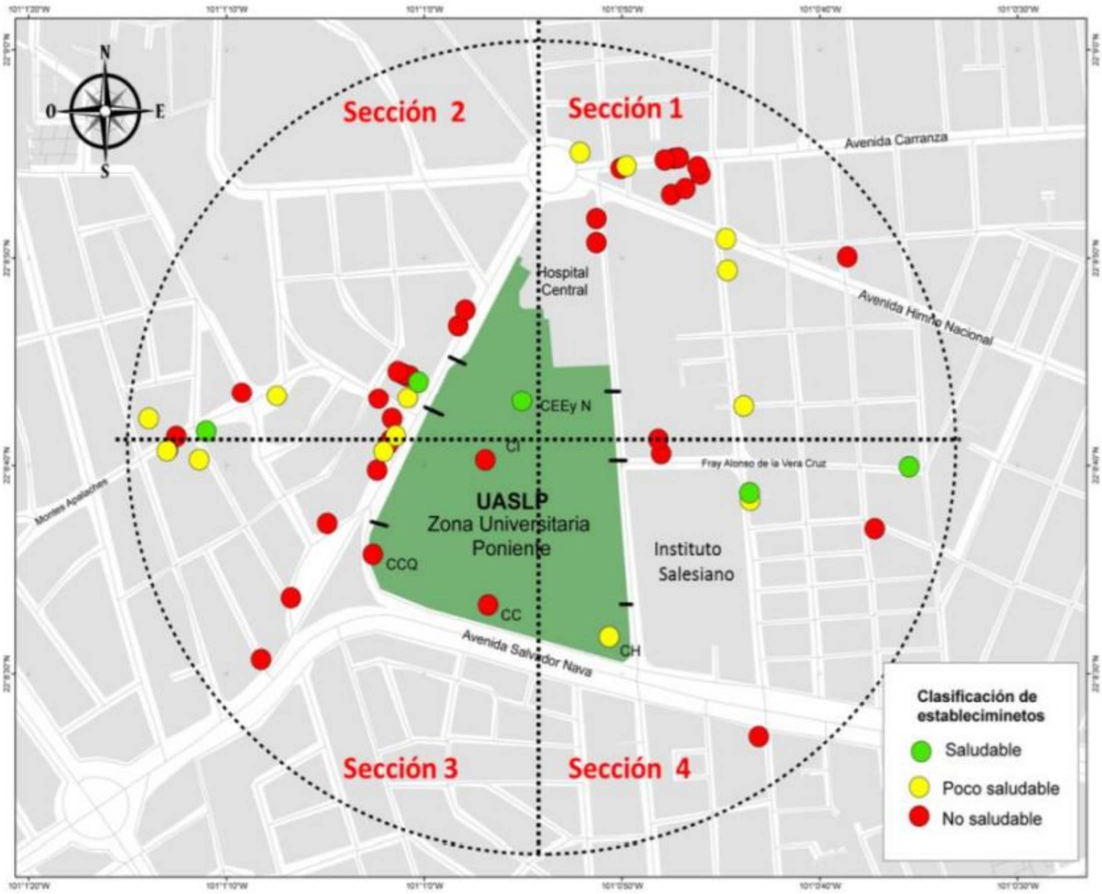

Figure 18. Distribution of food expenditures according to their nutritional classification (Ayala, 2017).

From the 130 food expenditures that were mapping for the study (having a buffer area of 600 m), 52.7% of them offered processed meals with high caloric contents. Furthermore, it was concluded that the surrounding area UASLP western campus is classified as a food swamp (due the high offer of unhealthy food), and it was estimated that only 9% of the food expenditures offered a healthy option.

The results of this study can be associated with the results from the food policy analysis, the fact that the food system has been centralized in the previous decades, and the lack of coordination across institutions, has created the perfect environment where access to healthy food becomes challenging. Therefore, based on the previous principles of the institution, and the goals presented on the

Development Institution Plan, it is essential to promote adequate actions within the institution that could provide the reference for wider scales.

One of the actions taken, was the project created by the Engineer and Habitat Faculties along with collaboration of the Division of Student Services, called "Unihuerto", which is a program that seek to address and raise awareness about the common issues that come along with unplanned urbanization, such is the case of food insecurity and poverty, social and spatial segregation, loss of biodiversity., by the recovery of spaces for the creation green areas for food production.

Based on this project, "UniTecho Vivo" is an initiative created within the UASLP west campus, which sought to recover the modified ecological structure, which has been lost in the development of the city through the transformation of roofs into diverse living spaces. Making reference on the role of food in the social structure, and how the expansion of areas for self-consumption are able to influence socioeconomic aspects and improve the quality of life of the participants. The beneficial impacts observed, have allowed the expansion of the project for some other UASLP campus, and at the time of this study, there are 5 Green roofs operating in the whole state which provide the tools and technical support for the interested population.

Through collaborative strategies, knowledge is generated and transmitted to individuals, and it is sought in the medium to long term to mitigate climate change under the principle of small collaborative actions. This institutional project provides spaces and resources to carry out field practices in various faculties of the university, in addition to the promotion of participation from the public through short courses in horticulture, composting, cultivation techniques and education for sustainability, which allows an understanding of the relationships and elements that the food system involve.

Since the establishment of the project, more than 3000 people have participated, 560 just in 2019, and it has been mentioned by the collaborators about the social implications and the necessity for mechanisms that allow and enhance the expansion of these practices are required, however, based on the limited budget, incentives, and most recently the implications of the COVID-19 pandemic, this project has remained limited for few beneficiaries.

Following the principles and objectives of the Milan Urban Food Policy Pact, actions on the growing centralized food systems are essential for the future in the urban centers, the conventional agricultural system has exacerbated the social gap between the sectors of the society, increased the levels of environmental degradation, and failed to provide affordable, healthy and nutritious food for the global population., moving forward from economies of scale to economies of scope is required as a way of providing deliberative democracy. The introduction of UA from the perspective of this study, can be adopted as a strategy for the democratization of the conventional food supply system, providing participative strategies that promote social welfare, inclusion, and sustainability. At the same time, being able to produce and enhance the ecosystem services that the deteriorated environment provides. The multifunctional capacity of UA can be considered as a lever for addressing multiple food and non-food issues, however, the policies and instruments that allow this are essential, and the experience gained by UASLP can be considered as the guidance to collaborate on a larger scale.

The good practices adopted and learned through the participation of the university community, can be transformed into principles and institutional policies for the university, which seek to address the social, economic, and environmental issues involved for the MASLP. The association of approaches, such is the case for the metabolism approach and the food policy analysis, can provide relevant quantitative and qualitative information for the study of food systems, in terms of understanding the underlying dynamic and driver forces involved, the impacts of the historical context and the feedback from the relevant actors. The formulation of policies addressed to these causes from part of UASLP, could become a case of success for the adaptation on a larger scale (such is the case of the UA initiative), therefore, for the following chapters, a technical implementation guideline for green roof was developed, which could be incorporated and extrapolated for other campus, as well, for further policies.

Chapter 5

Urban Agriculture within UASLP: building the blocks for the Green Roof guideline

Chapter 5. Urban agriculture within UASLP: building the blocks for the Green Roof guideline.

5.1 Introduction to Green Roof.

As previously discussed on chapter 2, Green Roofs have become an attractive alternative for governments around the world, due their potential to mitigate and adapt the rising relevant challenges occurring on urban centers. The benefits of Green Roofs can be presented as largely, however, it is important to understand the mechanism under which, these benefits can be achieved, and the implications involved in the creation and expansion of living areas in order to act properly. The expansion of green roof on a larger scale, can provide a large number of benefits for the inhabitants and the weather, by instance the presence of vegetation is able to modify and improve the microclimate in one area, improve the thermal comfort and reduce cost energies.

They are able to provide noise protection, since they work as insulators and absorbents, for this reason, they have been largely incorporated in areas with noise issues, such as airports and factories. On the same line, on areas with a deficit access to green or open spaces (such as previously discussed for the UASLP western campus) and provide additional protection to exposed buildings and by doing so, expanding their lifespan.

They can be studied and understood from different perspectives, aborded in terms of energy efficiency (which usually refers to the study of the energy transfers within the living medium), to the capacity for holding water and mitigate extreme rain events, to the analysis of the effects on the biodiversity on urban centers, along with the social implication for the creation of green spaces, and finally as a mechanism to promote circularity on the use of resources in cities.

However, since purpose of this study is the analysis for the **UA** introduction and a proposal for the food security enhancement within the **UASLP** western campus, the approach presented for green roof, consist of the possibility for integration of food productions systems based on agroecological principles.

5.2 Methodology.

Following the sequence established for this thesis, the purpose of this chapter provide a full extent on the building blocks required to to construct a green roof guideline for the western campus of UASLP, taking as a case of reference the project “Uni Techo Vivo”, this with the intention to be expanded and extrapolated for other areas, therefore, this intends to provide a descriptive tool that involves every single one of the elements to be considered for the construction, operation and maintenance, in order to maximize the benefits of the future projects.

For the structural analysis, a review on the relevant literature was performed in order to identify the most important aspects to consider during the design of a green roof such as the load capacity, effects of wind, slope and elevation. Furthermore, to complement the information obtained, interviews were performed with members of the project, to learn about their experience obtained since its formulation, and be able to provide more relevant and contextualized information of the case of study. As well, the information obtained in these interviews was also useful and used during the following sections of the guideline.

The selection of species for the area were made by the selection of criteria´s (and by the experience reported on the literature) and were presented depending on the type of use and requirements, therefore, 3 proposal were provided for each one of the types of green roof (Intensive-Semi Intensive- Extensive).

In order to illustrate the complexity of the systems and the necessity for constantly performing process of evaluation/reformulation, some of the most common criteria´s that are currently under study were presented and described, however, due the limitation on the access of the information, only few of them were considered and presented on the analysis. An additional remark to this, is that the vast majority of values presented were studied on land conditions, and it is relevant to continue with analysis of the conditions for this system.

Furthermore, additional information was provided for the management and maximization in the use of resources, as well on the incorporation of strategies that allow synergies within the system and the surroundings.

Figure 19 provides an overall picture of the components that were introduced for the further technical implementation guideline in the UASLP western campus.

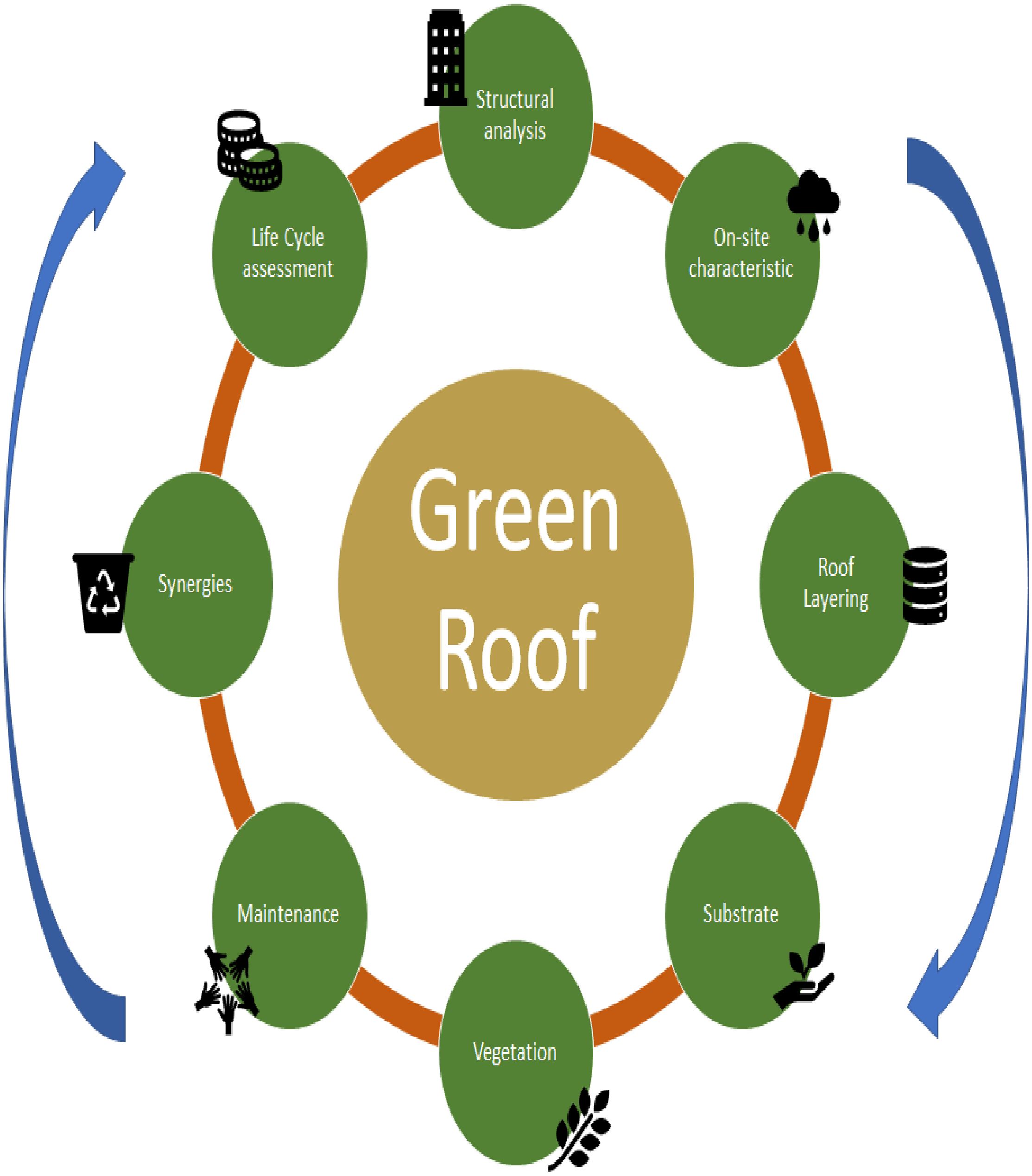

Figure 19. Components to consider for the formulation of a Green Roof.

5.3 Structural Design and the Surroundings.

5.3.1 Structure Loading Capacity.

When analyzing the load capacity of a building it is important to make a remark on the different king of loads and the role they play within the green roof. They are characterized as living and dead loads. The Living loads consist of all the weight added to the roof on a temporal period, such is the case of human traffic, snow, maintenance equipment, safety elements, etc. On the other hand, the dead loads are conformed by all the permanent weight of the roof, this includes the different kind on layers and the installations required. Therefore, both loads must be considered properly in order to make an adequate analysis of the structure, and determine the feasibility of the building, or the necessity for reinforcement. A strategy for this could be the categorization of the area in the building, which determines the spaces for use and the ones that would be excluded from access.

As claimed by to the Mexican federal norm NADF-013-RNAT-2007, green roofs can be classified according to their level of use and the weight of the system, for instance, extensive green roofs substrate should not be deeper that 15 cm and their saturated load must remain between 110 and 200 kg/m2. For semi-intensive green roofs, the depth of the substrate should have a minimum of 15 cm and a maximum of 30 cm, therefore, the saturated load generally remains around 200 and 350 kg/m2. For the intensive green roof systems, substrate depth should be at least above 40 cm and the saturated load surpasses 350 kg/m2 which would vary according to the requirements and the intentions of the site.

Particularly for the case of UASLP western campus, the building regulation of the municipality of San Luis Potosí on its article 210, stipulates the nominal load values that must be fulfill according to the kind of building. Based on this regulation, the load capacity of the buildings in the campus may vary from 170 to 350 kg/m^2, which could be useful for the determination of the load capacity of the building and the alternative possibilities for the implementation.

Therefore, we can deduce that the analysis of loads should be considered as an iterative process, from which the relations between the layers, substrate, and vegetation play an important role since they contribute with the higher weight loads for the building, and it is relevant to understand the requirements (in case of required reinforcements of the structure) and relations between them, in order to guarantee healthiness, safeness and longevity of the roof.

5.3.2 Slope.

Slope rate is another relevant element that must be considered prior de design, due the large number of variables that it is associated with, by instance, in places where the slope is higher than 2%, additional measures have to be taken in order to avoid an increased amount of run-off water.

According to the FLL guidelines and NADF-013-RNAT-2007 (which is one of the most relevant guidelines considered for this study), 2% of slope should be considered as the norm or requirement for a conventional arrangement of green roof. For those cases where the slope is higher than 5%, a layered superstructure with a fairly water storage capacity and poor drainage must be considered to compensate the potential losses of water. As well, for the roofs where the slope is less than 2%, additional measures and adjustments should be performed to avoid waterlogging.

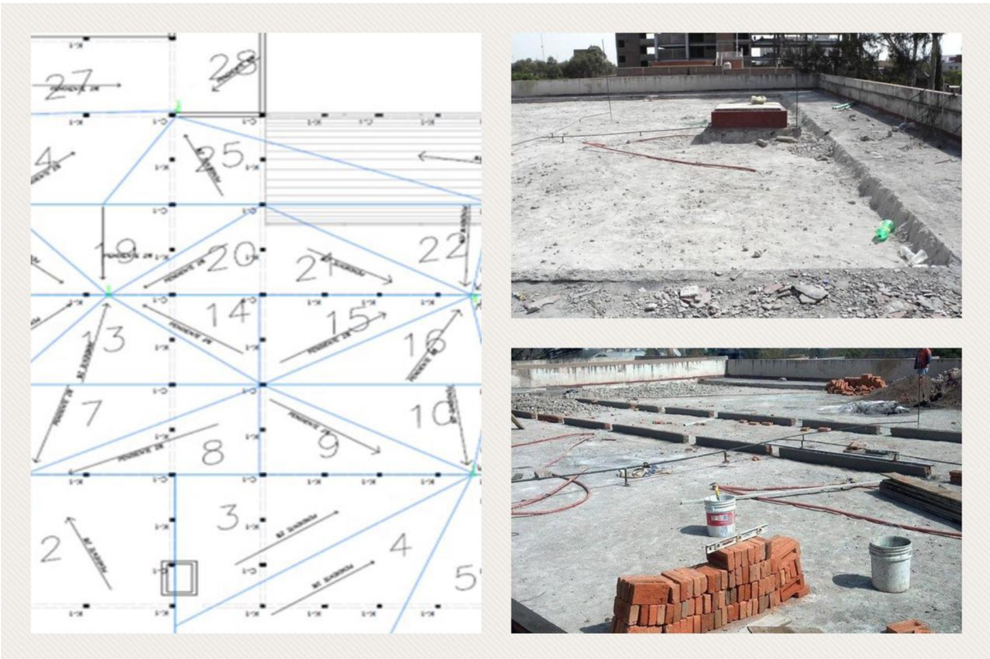

Figure 20. Slope Analysis and adequation.

5.4 The local analysis.

5.4.1 Weather.

Weather plays a decisive element during the design and formulation of a Green Roof, the variation on the temperature and the precipitation rates are usually considered as the dominant factor for the selection of species and substrate. Therefore, an analysis of the weather for the implementation area should be performed in order to identify the relevant aspects. By instance, the levels of precipitation and its distribution along the year play a major role for the selection of species and the necessity for alternative sources of water. In addition, temperature is also a highly relevant component to be considered since it would determine the metabolic capacity of the plants and the water requirements. Therefore, making use of tools such as climographs, could be useful for the analysis of the weather in the implementation area. **Figure 21** shows some of these tools for the analysis in the UASLP western campus.

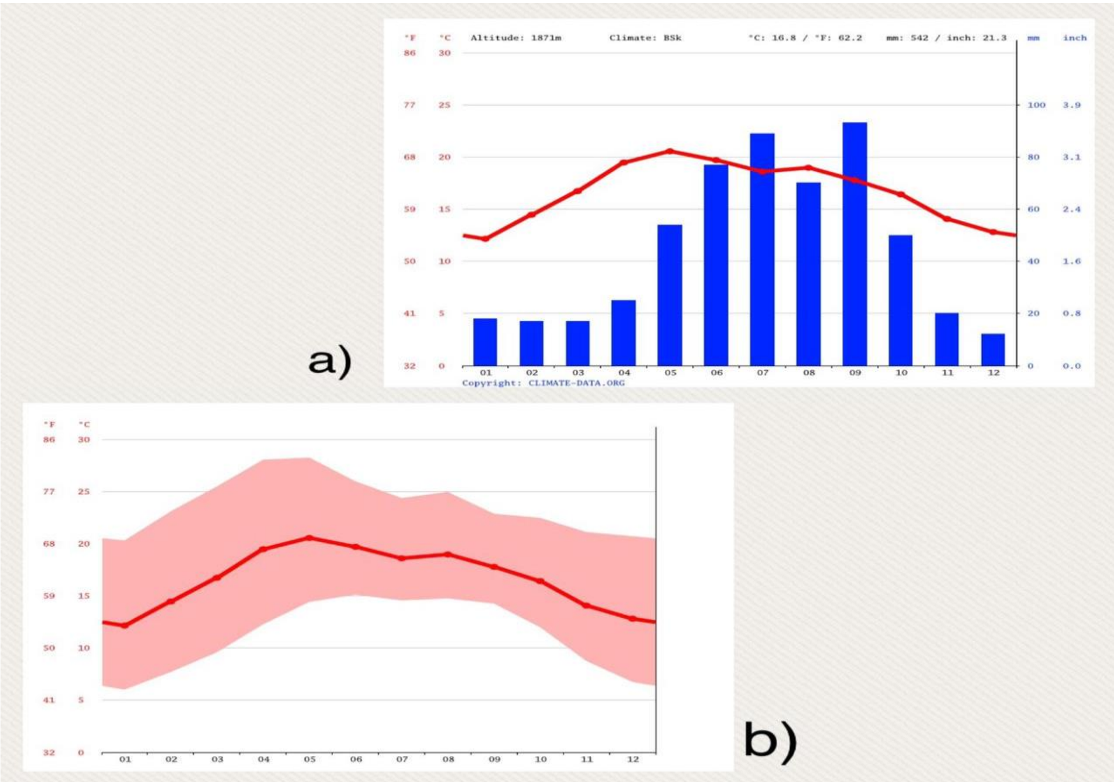

Figure 21. a) Diagram of the average temperature, and b) Climograph for the MASLP. Source: Climate-Data.org

5.4.2 On-site considerations.

The role that takes place the intrinsic characteristics of the building and the surrounding area is highly relevant during the design and formulation of the system since these conditions can affect the performance of the Green Roof. The conditions to consider during this stage are the following:

- Shading. Adjacent taller buildings can provide additional shading to the Green Roof which can become an important challenge for the energy provision of the plants. Consideration about the orientation of shadows should be made and it can even be used as an advantage by effectively locating shadow tolerant plants in the affected areas.
- Reflection. On the same direction, the adjacent building can also provide additional reflection and amplify the sunlight intensity which could create water stress conditions for the plants. For these cases, additional watering should be considered as well as the incorporation of drought and heat tolerant plant varieties.
- Exposure. Reduction of wind and exacerbation of extreme weather can be produced by the effect of the surrounding taller buildings, for the cases where the implementation area is oriented downwind of the common weather patterns is more likely that these conditions will prevail. However, for areas with an upwind orientation, the effect would be the opposite and a greater accumulation of water can be expected.
- Access for people. Enabling a safe and effective access for to the Green Roof is essential and should be considered since the design, because for some buildings, this process might involve major adaptations on the infrastructure which would also involve a biggest cost. Adjacent building could also provide effective access for the Green Roof; however, a proper configuration and adaptation of the area should be performed.

5.4.3 Elevation.

Accessibility to the green roof must be considered prior the establishment, by instance higher elevations might involve higher costs due the energy and material requirements. Furthermore, consideration about the wind effect since it can affect the stability of the system and increase the substrate erosion.

The pressure provided by the dominant wind loads need to be examinate at the design and planning of the green roof. Due the physical condition of the site, perimeter requires certain protection from the wind loads, a phenomenon known as wind vortex effect, takes place where the wind travels up and creates negative pressure at the surface. Therefore, corners and edges are usually considered as high stress areas unlike the central area where the level of stress is dramatically reduced.

Consideration about the substrate, plants and materials has to be made in areas where the wind speed might represent a higher risk, hence, well rooted plants and heavier materials for the substrate might become an additional alternative to protect the perimeter of the roof. The establishment of plants with a higher level of wind resistance could potentially improve and reduce on general terms, the levels of erosion for the green roof.

5.4.4 Potential Sources of Pollution.

Urban green areas (either for recreation or food production) are usually more exposed to be pollution by organic agents and trace metals, therefore, the proximity to the sources of pollution can play an important role on the assimilation of these pollutants. As argued by Saumel (2012), the three major sources of pollutants are associated with, a) use of contaminated soils, b) crop irrigation with polluted water, and c) airborne pollution by traffic or industrial emissions., however, an estimation of the assimilation rate is complex because it would vary deeply according to the characteristics of the area and the vegetal varieties. Therefore, guaranteeing the safeness and quality of the resources, and the most suitable location of the Green Roof is relevant to reduce the exposure to pollutants and maximize the healthiness of the plants.

5.5 Water Proofing and Layering.

Green Roofs are usually considered as artificial spaces that seek to mimic the complexity and interconnectivity of natural systems, nevertheless, due the complexity on the number of elements and relations that can be found, only few elements can be considered during the process of formulation and implementation.

Therefore, this section would provide relevant information about the elements to consider for the adaptation of the roofs with the purpose to provide a barrier between the physical inert support and the living media.

5.5.1 Waterproof Membrane.

This membrane can be referred as the main protection mechanism that all the roofs (weather or not is green) commonly use to protects the exposed paved surface from typically and untypically events of rain, and also provides protection (on a lower level) to the solar radiation. This layer becomes the elementary base to support the green roof as a differentiated system from the building, whereby, the quality and effectiveness of this layer is essential to guarantee the longevity of the area.

There is a wide variety of materials and still some on continue development for the construction market, among the most common are the bituminous flexible membranes (which can be classified as elastomeric and plastomeric), plastic, rubber, and liquid membranes, etc. Nevertheless, there is a big debate about the impacts from the large use of this materials and the need for new alternatives. Among their most relevant characteristics are the dimensional stability, cold flexibility, resistance to static loads and artificial ageing (Lucket, 2009).

In order to provide assistance during the design and formulation of the Green Roofs, **table 5** provides relevant information for some of the most common used materials for waterproofing the roof, however, the selection of the material would become a part of the iterative process which will depend of the purpose of the area, the infrastructure characteristics, and the element of the living media (such as substrate, vegetation, and requirements).

Material.	Durability.	Root resistance	Thickness (lb/ft^2)	Cost.
EPDM	**High**	**High**	**0.29-0.63**	**Low**
TPO	**High**	**Medium**	**0.23-0.42**	**Medium-High**
PVC	**High**	**High**	**0.23-0.42**	**Medium-High**
Built-up Roofing	**Medium**	**Low**	**2-3**	**Low**
Modified Bitumen	**Medium**	**Low**	**1-1.75**	**Low**
Liquid-applied Membrane	**Medium**	**Low**	**0.75-1.5**	**Medium**
Metal Roofing	**High**	**High**	**1-1.5**	**High**

Table 5. Compilation of waterproof membrane materials and their relevant characteristics.

It is important to mention that the maintenance of this layer is very difficult because in the presence of leaks when the green roof is operating, all the layers have to be removed, which might become a major cost for the roof. The relevance of the of this layer relies on this fact and it should be considered during the design and formulation. In addition to this, additional measures can be considered to protect from degradation over time, prevent infiltration, and reduce the effects from the upper layers.

As can be seen on **Table 5**, not all the common materials used as waterproof membranes in green roofs provide an effective resistance for roots and microorganisms, that is why additional protection layers or as usually mentioned “Anti-root membranes”, can be introduced to expand the longevity of the system, and reduce the maintenance requirements.

5.5.2 Anti-root membrane and protection layer.

The vegetation behavior has become relevant for the study of green roofs, and the capacity of root expansion on some varieties might result on damages in the structure of the roof. Therefore, the use of additional components such as the Anti-root membrane to delay this growth could be beneficial as a precautionary measure.

The purpose of this layer is to act as a protection segment to the waterproof membrane and the roof structure from vegetative roots from the upper layers. It is important to consider the root expansion rate of the plants selected for the site, as some of them have a high tendency for expansion, which might tend to create conflict between the layers. For some of those cases, micro-organisms additives are usually included for the anti-root membrane to repel their growth.

For the cases where the waterproof membrane provides a low root resistance, this root should be considered essential, as a mean to guarantee the integrity of the previous layer and the accessibility to the building for the roots. Some authors mention that this layer must be always considered, despite the repellent capacity of the waterproof membrane (Cascone, 2019, Vijayaraghavan, 2016). There is already a large number of commercial anti-root membranes, which mainly consist of hard plastic sheet or metal sheets (usually copper), however, anti-root membranes with heat welded seams might be required to provide additional protection to more aggressive roots (Lucket, 2009).

In addition to this precautionary layer, a good practice that has gained relevance in the study of green roofs, is the implementation of an additional separation and protection layer between the previous and the upper layers. This layer could also work as a water reservoir for the substrate and vegetation in periods of hydric stress. However, this layer should be able to withstand load and pressures during the construction and operation of the green roof, therefore, the most commonly adopted materials with these features are the geogrids, geotextiles, and polystyrene. It is important to mention that these materials should have a thickness of at least 3 mm and a compression resistance and a compression resistance >150 Kpa (Cascone, 2019).

5.5.3 Drainage Layer.

Once that the previous layers have been selected for the protection of the building, the selection of the drainage layer is essential to guarantee the healthiness of the growing media and the vegetation, since it is the layer that is able to provide an adequate distribution of air and water between the upper layers. Due their components characteristics, this layer can remove the excess of water and provide enough air to the substrate. This is highly beneficial since it can reduce the weight load and avoid mechanical breakdown.

In order to avoid failures that might result on low levels of aeration, the drainage layer should be filled with at least 60% of air to preserve the vegetation, prevent deterioration, and reduce effectiveness over time (Jiang and Tang, 2017). The mainly types of drainage layers used for green roofs due their effectiveness and accessibility, are the following:

Granular Materials: They are composed by a large combination of aggregates, from which stand out, lapilli, expanded clay, expanded pearlite, expanded slate, pozzolana, pumice, among others. The recommended thickness for layering according to the literature (FLL, Year, Cascone, 2019, Vijayaraghavan, 2016, Lucket, 2009), they are usually 6 cm thick and should have a minimum density of 150kg/m^3. These materials also have some water holding capacity due the pores of the materials, however, if a higher water holding capacity is required, these materials might not become the best option. In addition to this, one of the aspects to consider when adopting this alternative, is that they are only eligible for roofs with a slope no higher than 5 °.

Modular Panels: This alternative consist of prefabricated panels that are produced with high resistant materials (such is the case of polystyrene and polyethylene), with a thickness between 2.5-12 cm and a weight of about 20 kg/m^2. In addition to this, due their large pore distribution, this layer can provide a highwater holding capacity for the substrate and the vegetation. According to some studies, they are able to store from 2 to 4.3 L/m2 of water depending on the manufacture (Vijayaraghavan and Yoshi, 2014, Wong and Him, 2014).

Figure 22. Commonly used materials for drainage layer.

Table 6 provides the operational requirements to fulfill for each one of the drainage materials mentioned, however, these requirements are different from granular to modular materials due their intrinsic characteristics.

Granular Materials	Value	Modular panels	Value
Permeability	i> 0.02	Draining capacity	0.7 l/m2s
Compressive strength	> 1.5 N/mm2	Longitudinal tensile strength	>7 kN/m
Thermal conductivity	λ< 0.2W/mK	Tensile strenght	>7 kN/m

Table 6. Reference values for drainage layer.

Once that the principles and operational basics have been discussed, it is important to mention that the selection of the drainage layer relies a deeply connection among many elements such as the structural characteristics of the building, the location, size of the roof, costs, roof slope, substrate, and vegetation. By instance, for extensive green with vegetation that require low levels of substrate and irrigation, granular materials are the most used since they are economically affordable and can be integrated with local material in the surrounding areas, nonetheless, as previously mentioned this can only be incorporated for roof with slopes no higher than 5°. For large scale intensive green roofs where a higher water holding capacity is required, modular panels have a better performance, and they can reduce importantly the weight loads compared to the granular materials, furthermore, installation, maintenance, and disposal, are facilitated.

5.5.4 Filter Layer.

The following section is the filter layer, which functions as barrier between the drainage layer and the substrate, this segment also avoids the entrance and blocking of smaller particles and roots coming from the substrate to enter the drainage layer. On practice terms, geo-textiles fabrics are the main kind of materials used for green roofs (either is extensive or intensive), they should have a high resistance since they should be able to withstand the loads above, **Table 7** provides some of the basic parameters to fulfill during the selection of this layer, furthermore, this layer should have pores to allow water permeability to the drainage layer, which can be usually considered as 10-12 times higher than the substrate.

The thickness of the layer might be a relevant aspect to consider when retention of water is intended to be improved, studies made by Bisceglie *et al* (2014), showed that green roofs with herbaceous plants and thicker fabric materials retained over 300% more precipitation compared to thinner materials. Other estimations point out that these non-goven geotextiles can absorb approximately 1.5L of water/m2 (Wong and Jim, 2014). Meanwhile it can provide additional water storage, it is something that should also be including during the load analysis of the building.

In some of the commercial materials, chemical compounds can be found attached to the layer in order to repel root growth which serves also as an additional anti-root membrane, nevertheless, that should be verified with the manufacturer.

Punching resistance	>1100kN
Longitudinal tensile strength	>7kN
Transverse tensile strength	>7 kN
Deformation to the longitudinal operating load	<60%
Deformation to the transverse working load	>60%
Effective pore opening	0.1-0.2 mm
Oscillation resistance	< 20%

Table 7. Basic requirements to fulfill during the selection of the filter layer.

5.6 The Roof Substate.

5.6.1 Substrate principles for the Green Roof.

Analysis and selection of the most suitable substrate has to be considered as an iterative process along with the selection of vegetal species due the high level of interactions, a deeper understanding of the each one of the elements that conform this phase is essential, such is the case for the synergies that take place along the phenological stages., the elements, components and capacities that conform the soil and the requirements to be fulfill, are essential to be acknowledge in order to guarantee the long-stand subsistence of the green roof.

Substrate can be defined as the ion exchange medium that would allow the access to resources for the plants, therefore, research to understand the interaction from a several kinds of arrangements of substrates in green roofs is rapidly increasing in order to optimize and maximize the potential benefits.

Table 8 provides the most relevant parameters (categorized physical and chemical) to be considered during the determination of the substrate, however, this decision should go along with the determination of the species which will determine the requirements to fulfill in order to maximize their maintenance and growth.

Physical	Chemical
Density	pH
Particle size	Electrical conductivity
Water permeability	Leaching capacity
Water Holding Capacity	Chemical structure
Maximum air volume	Quantity of organic matter
Low bulk density	High sorption capacity

Table 8. Relevant characteristic to consider during the substrate decision making process.

At the moment of this study, the majority of reported data and studies that can be found in the literature makes reference for the extensive roof substrates, since they are largely being incorporated as a mitigation mechanism for flood managements and energy saving within urban centers, and there relies their relevance, however, one of the main differentiations relies on the amount of organic material that it is required. By instance the German guidelines for green roof (FLL, Year) recommends that the organic matter proportion should not surpass 12% (either for intensive or extensive), nonetheless, for the food production designated areas this should not be considered as the reference.

An additional aspect to be considered during the selection of the substrate, is that the composition of the substrate plays a relevant role on the thermal resistance of the building, meanwhile, it is usually not considered as an insulation layer, the capacity of water retention influences significantly the thermal conductivity.

5.6.2 The load implications of the substrate.

The selection of substrate plays a major role during the design and formulation of the Green Roof since it is the element that contributes with the higher load of the system. As previously mentioned, Green Roofs are usually classified from Intensive (>350 kg/m^2), Semi-Intensive (between 200 to 350 kg/m^2), and Intensive (from 110 to 200 kg/m^2), and this is mainly for the soil and water requirement of the plant which must be provided for their maintenance.

On general terms and as guidance refence, substrate bulk density varies from 12-14 kg/m^2 for thickness of 8-10 cm in extensive green roofs, meanwhile, for intensive green roofs with a thickness of 40-60 cm, the average bulk density is about 600 kg/m^2. Therefore, based on the purposes and capacities of the green roof, and the vegetation varieties that are intended to introduce, a selection of criteria should be considered for a proper selection of substrate. Since the underlying objective of this guideline is to become part of a food security program, it will be relevant to fulfill with the requirements for this purpose, however, a differentiation between the kind of roof and substrate will be provided.

Moving forward, some of the relevant alternatives for the substrate during the consolidation of the Green Roof are perlite, vermiculite, and coco-peat, because these materials can provide desired features such is the case of a high-water holding capacity, porosity, hydraulic conductivity, and most importantly a low bulk density in order to reduce the load requirements of the building. Nonetheless, it can become economically challenging according to the location and availability.

Some other studies point out to the formulation of substrate composed by several materials in order to maximize their features and reduce weight loads. By instance, some studies suggest that alternative low-cost and light weight substrate can be obtained by a combination of materials such as pumice, zeolite, scoria, vermiculite, peat, and crushed brick (Zhao *et al*, 2014, Bates *et al*, 2015).

Additional studies have been able to report important results by the combination of organic and inorganic materials, such is the case for perlite (30%), vermiculite (20%), crushed brick (20%), sand (10%), and coco peat (20%), and by doing so obtaining a low bulk density substate with a low bulk density of 431 kg/m3 Vijayaraghavan and Raja, 2014). Additional estimations about the performance and features of commercial substrates can be found on the literature, however, for the countries where the Green Roof products are not widely available, the introduction and mixing of local materials would play a major role. Nonetheless, the criteria previously discussed can become as the reference and the guidance to achieve a healthy, long-lived, and effective substrate.

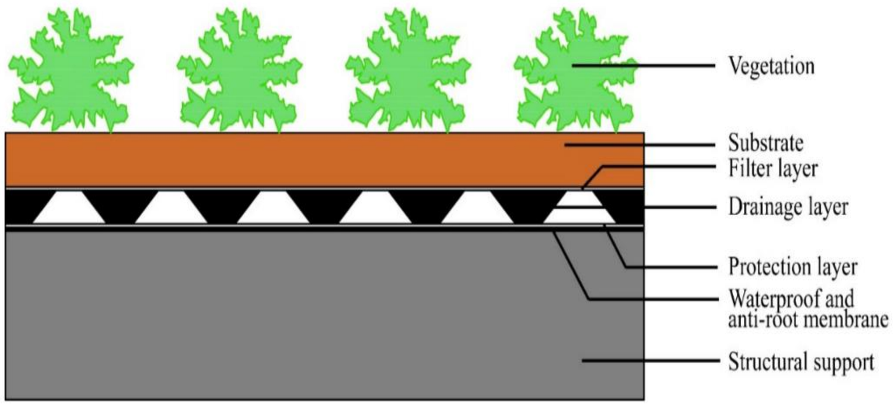

Figure 23. Configuration of layers for the Green Roof.

5.6.3 Feasibility for local materials.

The feasibility for a large-scale introduction of Green Roofs in urban centers demands for a constant evaluation about the most suitable materials for each one of the layers, however, in terms of the substrate and regarding about the implications of long-distance transport, it is important to incorporate during the formulation of the system, the use of local materials. By instance, the **MASLP** due the location and proximity to some of the most relevant chain of mountain ranges ("Sierra Madre Oriental" and "Sierra Madre Occidental), is a location where the incorporation of local and adequate materials for Green Roofs becomes highly feasible. The lithological characteristics of the area can provide many materials from igneous, sedimentary, and metamorphic. However, based on the parameters described and the structural capacities of the place, a characterization and analysis of the most feasible alternatives should be performed in order to establish mechanisms for adaptation and enhancement.

5.7 Analysis and selection of plants

Urban centers are characterized for the high level of elements that interact and feedback each other, creating an environment of high uncertainty where the number of elements to consider for the consolidation of any system are constantly increasing, therefore, it is important to analyze and identify the potential elements (in terms of hazardousness) for the uppermost living layer of the Green Roofs. It is important to mention that roofs are not favorable environments for plant growth since there are several limitations when these spaces are intending to mimic soil conditions, therefore, the types and varieties of vegetation are usually limited. This limitation becomes more evident during the selection of the kind of roof since the structural capacities can determine the soil characteristics of the substrate.

For the case of extensive green roofs (where most of the literature and empiric evidence is found) the major characteristics of the vegetation that are intended to achieve are: a) drought tolerance, b) minimal nutrient requirements, c) ground coverage, d) low maintenance, and e) fast development. Consequently, succulent vegetation has become extremely attractive for the use in Green Roofs. Among this large type of vegetation, *Sedum* species stand out as the most popular and effective plants, since they are able to adapt, resist droughts, maximize the use of water, and provide energy savings (Blanusa *et al*, 2013).

Intensive green roofs vary highly on these elements, since the use, intention and purpose can be completely different. On general terms, the intended features are similar than the extensive, however, the requirement vary importantly because the physiology of the plants are quite different. Nonetheless, by allowing a larger diversity of plants, the function and performance of the ecological community can be enhanced and by doing so, promoting beneficial effects such is the cooling of the building, avoid of invasive weeds, and conservation of water.

Following this and based on the principles of agroecology, hybrid communities are proposed as the best alternatives for Green Roofs whose purpose are the contribution to food security and the recovery of ecological structure. Hence, a booklet of criteria is provided below, which can be useful for the formulation of each vegetative segment of a Green Roof. Although only some of them were considered during the proposal due their relevance and accessibility.

Metabolic Pathway.

Photosynthesis is the metabolic process from which the plants are able to obtain the required energy and compounds for their maintenance through the assimilation and transformation of carbon (CO_2). However, through evolution the mechanisms from which this assimilation of carbon has change for some plants, where the oldest is the metabolism C3, followed by C4, and finally CAM (which refer to the organic compounds that are produced during the process). A brief description of the relevant aspects of each metabolic pathway is provided which could be useful during the selection of vegetation. These differentiations can provide explanation to some phenomena that constantly take place in the study of vegetation. By example, metabolic differences among species have been proposed as an explanation for the high trace metal contents found in leafy crops compared to other crop types (Geetal, 2000).

C3 Photosynthesis.

C3 photosynthesis pathway is defined as the metabolic process adopted by plants for fixing CO2 from the atmosphere for the Calvin Cycle, which consist of a large process of chemical reactions that allows the conversion from CO2 into glucose, they are referred as C3 plants for the three-carbon compound produced from the chemical reaction of in the Calvin Cycle. It has been estimated that more than 90% of land plants have a C3 photosynthesis pathway (Raya and Mancilla, 2008). A relevant aspect to mention is that the majority of plants with this metabolic pathway are not very tolerant to conditions of water stress or high temperatures, because they shut their stomas to reduce the loss of water but by doing so, the entrance of CO_2 is detained.

C4 Photosynthesis.

C4 pathway has emerged from the adaptation of some plants from hot habitats and few from cooler areas, this arrangement is characterized for having step of carboxylation of the fixated carbon before the Calvin Cycle, which creates a 4-carbon acid. The C4 pathway is used in about 3% of all vascular plants; some examples are the crabgrass, sugarcane, and maize (Snyder, 2019), which prevail in hot weathers due their capacity to minimize photorespiration.

CAM Photosynthesis Pathway.

Crassulacean acid metabolism or as usually referred as **CAM**, is a carbon fixation pathway that plants from arid condition have adopted and evolved for their subsistence, which allows plants to photosynthesize during the day. Plants with CAM photosynthetic pathway are able to collect carbon dioxide (CO2) at night for later use in photosynthesis with the purpose to avoid higher losses of water (evapotranspiration) and maximizing the use of water which makes them drought tolerant (Wolf et al, 2008).

Daily Light Integral (DLI).

This criterion, which is commonly referred as DLI, is highly used for food production systems, and it is defined as the amount of photosynthetically active radiation received by plants on a period of 24 hours, and it is expressed in moles of light per square meter per day (mol/m^2d). The reason about the relevance of these criteria is because it is directly related to the plant growth, yield, quality, and development. Therefore, this could be useful for the selection of the varieties for food production since each area varies in terms of radiation.

Leaf area index (LAI).

Another relevant aspect that is highly relevant when energy assessments are performed is the leaf area index (**LAI**), which is a dimensionless parameter that is defined as the one-sided green leaf area per unit ground surface area, and it is commonly used as an indicator of the growth rate of a plant. Values of LAI, depend on the type of plant and the typical range goes from 0.5 to 5, consequently, the highest level of LAI (LAI=5), corresponds to an increase of energy consumption in winter and reduction in summer (Berardi *et al*, 2014).

Stomatal Resistance.

Stomatal resistance is a biophysical parameter that governs the rate at which the plant transpires moisture, the stomata are the intercellular openings between epidermal cells on the leaf of the surface and their closing and opening rules of transpiration. Therefore, this parameter is highly relevant to determine the Evo transpiration rates in order to establish more suitable varieties.

Nitrogen.

Despite from being one of the most abundant elements in the atmosphere, Nitrogen is usually considered as the main requirement for food production, and soils require a constant process of nutrition and enhancement in order to guarantee the basic requirements for plants development. Nitrogen plays an important role during the metabolic process of plants, and the preferent ionic forms that prevail in soils are nitrate (NO_3^-) and ammonium (NH_4^+). Therefore, if fertilization of substrate is conducted, the elements that conform the fertilizer (if they have been evaluated) should be consider with the purpose to optimize vegetal nutrition.

On general terms, where there is a deficiency of nitrogen for the plants, might be appreciated with the chlorosis of the plant which is a process provoked by the lack of chlorophyl that produces the yellowing of the leaf tissue, the early maturation and the absence or diminished amount of fruit. Some other cases, such is the case of tomato and maize, that the leaf shows evidence of purple pigments. Nevertheless, the concentration of nitrogen should not surpass some limits that depend on the requirements of the plants, excess of nitrogen can result in vast foliage with a considerably reduced amount of fruit, at the same time, plants will be subjected to disease and insect infestation.

Phosphorous.

Phosphorous is also a macronutrient that is essential for vegetation growth due the role it plays during photosynthesis, respiration, and metabolism. It is commonly available in substrates for plant assimilation as the phosphate ion (PO_4^{-3}), in most plants, phosphorous is distributed easily from one organelle to another accumulating in the young leaf, flower and seeds. One of the main drivers that facilitate the absorption of phosphorous in natural conditions, is the presence of mycorrhizas. To a large extent of plants, deficiency of phosphorous will induce a slow and stunted growth, purple coloration in the older leaves and an intense green in young leaves might be characterized as a symptom por deficit, similarly, reduction on grain and fruit yields are evident. The effect of phosphorus excess is usually not that evident as some other macronutrients, nonetheless, high values might affect the absorption of some other micronutrients such as calcium, zinc, iron, and magnesium.

Potassium.

Behavior of potassium is similar than phosphorus in terms of transport, absorption, and presence. It is considered as an essential macronutrient because it performs an important role in the osmoregulation that occur in the opening and closure of stomas. A higher susceptibility for pest that attack the roots and stems is commonly associated with potassium deficiencies which at the same time, make the plants especially sensitive to the action of wind and rain. Some other elements to be recognized are that older leaves might look burned by and effect known as scorch, and the quality and amount of fruit are consistently reduced. Excess on the amount of potassium might result in a diminished absorption and transportation of calcium and magnesium required for the plants.

Magnesium.

This element usually becomes a limitation in highly acid or sandy substrates, the relevance of magnesium relies on the capability of carbon and nitrogen assignation in the chloroplast, which will vary according to the Mg^{+2} concentration, furthermore, it also takes a major role in the energetic metabolism and the biosynthesis of proteins. Deficiencies on magnesium can be associated with the transport that occurs from the older leaves to the youngers, which is appreciable by the effect of chlorosis.

Micronutrients.

This category is composed by Fe, Mn, Zn, Cu, B, Mo, Cl and Ni. Meanwhile they are as important as the macro nutrients, the amounts required for the homeostasis of the plant are minimal, and they are still under study.

Hardiness Zone.

This is a concept which was initially developed by the United States Department of Agriculture (**USDA**), which consist of categorizing vegetal varieties according with the weather conditions. This criterion serves as an illustrative alternative for the definition of species, however, due the high adaptability of certain plants, some other elements should be considered for the decision. Therefore, it was used as a reference for the formulation of the plant proposal, along with other elements that enriched the analysis.

5.7.2 Proposal of plants for Intensive Green Roof.

Once that some of the relevant criteria have been described, this section provides a vegetation proposal for the **UASLP** western campus. This proposal was categorized according to the vegetal variety (in terms of substrate requirements), and the purpose. Therefore, the first section provides a proposal of plants for food production based on the experience from the collaborators of "Uni Techo Vivo", which was also complemented by data found on the literature. However, it is important to make the distinction that the values provided are obtained on soil conditions, so the evaluation of the behavior and dynamics that could differ on Green Roof is relevant for further studies.

Following this, the vegetation proposals for semi-intensive and extensive roofs was created based on the analysis of several guidelines (Arabi *et al*, 2015, Caneva et al, 2015, Getter and Rowe, 2008, Kohler and Poll, 2010, Luckett 2019, Proksch, 2011, Snodgrass and Snodgrass, 2006,), as well as by their contextualization based on the local conditions and capacities of **UASLP** western campus.

Specie/Variable	Water requirement (mm/total growin period)	Metabolic Pathway	pH (Optimum value)	Nutrient Sufficiency Ranges (%)			
				N	P (P2O5)	K (K2O)	Mg
Tomatoes (*Solanum lycopersicum*)	400-800	C3	6,0-7,0	3,0 - 6,0	0,3-0,8	2,5-5	0,5-1
Carrots (*Daucus carota*)	350-500	C3	6-7,5	3,5-6	0,25-0,8	3,0-7,0	0,25-1
Beans (*Phasiolus vulgaris*)	300-500	C3	6-7,5	3,6-6	0,3-0,7	2,0-4,0	0,35-1
Pumpkin (*Cucurbita spp*)	300-600	C3	5,5-7,5	2,5-4,5	0,4-1	3,5-5	0,3-0,5
Onion (*Allium cepa*)	350-550	C3	5,5-7	2,5-4,5	0,4-1	3,5-5	0,3-0,5
Lettuce (*Lactuca sativa*)	350-600	C3	6,0-7,0	3,5-6	0,4-1	3,5-8	0,3-1
Cabbage (*Brassica oleracea*)	350-500	C3	6-7,5	2,5-4,5	0,4-1	3,5-5	0,3-0,5
Parsley (*Petroselinum crispum*)	300-450	C3	5,5-7	3,5-6,0	0,4-1	3,5-8	0,3-1
Peppers (*Capsium Annuum*)	600-900	C3	5,5-7	3,0-6,0	0,4-0,8	4-6,5	0,5-1
Potatoes (*Solanum tuberosum*)	500-700	C3	5,0-6,0	4,0-6,0	0,3-0,7	3,5-6,5	0,5-1,1
Cucumbers (*cucumis sativus*)	300-550	C3	5,5-7	3,5-5,5	0,3-0,7	2,5-6	0,6-1,5

Table 9. Proposal of varieties for food production and their requirements.

5.7.3 Proposal of plants for Semi-Intensive Green Roof.

Specie/Variable	Family	HD	Plant Medium	Height (cm)	Spread	OM	Comments
Aethionema grandiflorum	Brassicaceae	5	15	20	30	Full sun	Needs additional water in dry periods
Alyssum serpylifolum	Brassicaceae	8	15	7	25	Full sun	More drought resistant than other Alysum species
Anthyllis vulneraria	Papilionaceae	7	15	15	15	Full sun/mixed/shade	Herbal Medicine
Aster alpinus	Asteraceae	3	15	22	15	Full sun/mixed/shade	Symbiosis with grasses
Bouteloua curtipendula	Poaceae	4	15	76	50	Full sun/mixed/shade	Drought tolerant grass
Bouteloua gracilis	Poaceae	4	15	30	30	Full sun/mixed/shade	Commonly found in Mexico
Buchloe dactyloides	Poaceae	4	25	20	30	Full sun/mixed/shade	Able to withstand foot trafic
Dianthus myrtinervius	Caryophyllaceae	7	15	10	20	Full sun	Can withstand drought better than other dianthus
Echium vulgare	Boraginaceae	3	15	76	20	Full sun	Introduced in America during colonial times
Erigeron glaucus	Asteraceae	3	15	20	25	Full sun	Salt tolerant
Fragaria chiloensis	Rosaceae	6	15	20	25	Full sun/mixed/shade	Wild edible strawberry
Herniaria glabara	Illecebracea	5	15	5	25	Full sun/mixed/shade	Higher tolerance to drought
Hieracium spilophaeum	Asteraceae	6	15	25	20	Full sun/mixed/shade	2-5 years for proper growth
Lavandula angustifolia	Larniaceae	5	15	40	25	Full sun	Can provide essential oil
Lotus corniculatus	Papilionaceae	5	15	10	15	Full sun	Usefull for nitrogen fixation. Might require aditional irrigation
Oenothera carspitosa	Onagraceae	4	15	20	30	Full sun	Very drought tolerant once established
Oenothera macrocarpa (o. missouriensis)	Onagraceae	5	15	20	30	Full sun	Good for attracting pollinators
Oenothera macrocarpa subsp. Incana	Onagraceae	4	15	20	20	Full sun	Drought tolerant
Origanum vulare	Lamiaceae	5	15	35	20	Full sun	Herbal green roof
Penstemon smallii	crophulariacea	6	15	55	25	Full sun/mixed/shade	Native for dry shade
Poa alpina	Poaceae	4	15	10	20	Full sun/mixed/shade	Fertilization required
Poa chaixii	Poeacea	5	15	25	20	Full sun/mixed/shade	Can reach 1,2 meters height under favorable conditions
Potentila aurea	Rosaceae	5	15	15	25	Full sun	High toelerance to acid substrates
Salvia officinalis	Larniaceae	5	15	50	30	Full sun	Culinary ornamental
Sesleria caerulea	Poaceae	4	15	25	30	Full sun/mixed/shade	Good performance on edges.
Silene acaulis	Caryophyllaceae	2	15	10	25	Full sun	Well adapted to high altitudes. Loof for info
Thymus pulegioides	Lamiaceae	5	15	10	25	Full sun	Can suffer with high levels of humidity
Veronica repens	crophulariacea	5	15	5	25	Full sun/mixed/shade	Can tolerate foot trafit with irrigation

Table 10. Proposal of varieties for semi-intensive Green Roof.

5.7.4 Proposal of plants for Extensive Green Roof.

Specie/Variable	Family	HZ	Plant Medium	Height (cm)	Spread	OM	Comments
Allium acuminatum	Alliaceae	7	10	15	15	Full/mixed/shade	Commonly extended in green roofs
Allium schoenroprasum	Alliaceae	4	10	25	15	Full/mixed/shade	Most common allium
Allium tuberosum	Alliaceae	7	10	38	20	Full/mixed/shade	Garlic chives
Delosperma cooperi	Aizoaceae	6	10	10	30	Full sun	High resitance to droughts
Delosperma ecklonis var.	Aizoaceae	6	10	10	25	Full sun	Rapid coverage
Jovibarba allionii	Crassulaceae	5	10	10	10	Full sun	Spherical dominance
Opuntia humifusa (syn. O. compressa)	Cactaceae	4	10	20	15	Full sun	High resitance to droughts
Rosularia muratdaghenis	Cactaceae	6	10	7	10	Full sun	Requires lean soil
Sedum album	Crassulaceae	4	10	15	30	Full sun	Is able to change between C3 and CAM carbon fixation
Sedum album "Chloroticum"	Crassulaceae	4	10	5	15	Full sun	Slow growth
Sedum album "Coral carpet"	Crassulaceae	4	10	5	20	Full sun	Very dense, turns red in drought
Sedum album "France"	Crassulaceae	4	10	20	20	Full sun	More presence and structure
Sedum dievergens	Crassulaceae	4	10	10	20	Full sun	Mild drought tolerance; check data
Sedum diffusum	Crassulaceae	8	10	15	20	Full sun	Very fast grower
Sedum griseum	Crassulaceae	10	10	20	20	Full sun	Might need ocasional water in drought periods
Sedum Mexicanum	Crassulaceae	8	10	10	38	Full/mixed/shade	Rapid spreader
Sedum moranense	Crassulaceae	8	10	7	30	Full sun	Very dense growth
Sedum oreganum	Crassulaceae	5	10	10	20	Full/mixed/shade	y need some irrigation, probable fo
Sedum rubrotinctum	Crassulaceae	10	10	20	15	Full sun	Shiny, succulent leaves
Sedum xrubrotinctum	Crassulaceae	8	10	15	15	Full sun	Great alternatives for small areas
Sedum spurium "Roseum"	Crassulaceae	4	10	15	20	Full sun	High resitance to droughts
Sedum sexangulare	Crassulaceae	4	10	10	20	Full sun	Highly adaptable
Sedum sthalii	Crassulaceae	8	10	15	15	Full sun	Good choice for southern roofs.
Sedum stefco	Crassulaceae	5	10	5	20	Full sun	Performs well in high wind areas
Sedum stoloniferum	Crassulaceae	7	10	20	25	Full/mixed/shade	Good for dry shades
Sedum telephioides	Crassulaceae	5	10	60	25	Full sun	allest sedum suitable for green roo
Sedum ternatum	Crassulaceae	5	10	7	20	Mixed Sun/Shade	Drought tolerant with protection from full sun
upervivum "Georgette	Crassulaceae	5	10	15	15	Full sun	Drought tolerant
Talinum calycinum	Portulacaceae	6	10	10	5	Full sun	Excelent choice for bee atraction
Talinum Parviflorum	Portulacaceae	6	10	20	10	Full sun	uited for very dry and windy locatio
Tulbaghia violacea	Alliaceae	7	10	50	15	Full sun	Society garlic, ornamental and drought tolerant

Table 11. Proposal of varieties for extensive Green Roof.

5.8 Maintenance.

One of the misstatements that is constantly address along the debate of Green Roofs is the miss and under consideration of maintenance role. It is commonly argued that watering is something marginal due the arrangement of the system, and therefore the activities for maintenance are minimal. However, this stage can be considered as one of the most relevant for consideration during the design and formulation of the system, since it is the one that would be able to mitigate the damages and provide actions to guarantee the beneficial effects of the roof.

5.8.1 Irrigation.

The selection of procedures for irrigation must be considered along with the building and area analysis since those results will be able to provide the additional annual water requirements for the plants. It is highly recommended to saturate the substrate (if possible) during the planting and propagation of the system in order to provide high levels of hydration during the vulnerable growth stages., for the case of extensive plants, a proper irrigation is highly relevant during the initial growth phase and should be performed every 3 or 4 days during a period of 6 to 8 weeks, before reducing it gradually. For the case of semi-intensive use plants and the designated areas for food production, the requirements should be fulfilled according to the minimum physiological demands that allow the proper growth without compromising their productivity.

Therefore, the selection of the irrigation strategy would depend deeply on the arrangement of the system (in terms of substrate, plants, maintenance, and location), which would determine the periodicity rates for watering of the Green Roof. Furthermore, the analysis to determine the technical and economic feasibility for the incorporation of automatized systems (such as dripping, sprinkler, localized, etc.) should be performed for the specific place, for the purpose of maximizing more effectively the allocation, distribution, and use of water for the substrate and the plants.

5.8.2 Fertilizing.

Green Roofs aim to mimic the natural conditions that commonly take place and allow growth vegetation; however, this becomes a limitation due the systematic conditions and the effects (negative of positive) of the surrounding area, hence, it is important to continue providing the deficiencies that might take place within the system. For the case of extensive use plant varieties, slow-release fertilizers (9-14 months) are highly recommended to guarantee the macronutrient requirements (15% N, 10% P_20_5, 15% K_2O, 2% MgO and less than 0.5% Cl). Nonetheless, for intensive use plant varieties, the requirements are highly different and would vary according to the phenological stage, consequently it is important to guarantee a constant base of nutrients. Additionally, synergies within the system should be allowed, such is the use of irrigation alternatives that provide nutrients (fertigation) directly to the roots, and the incorporation of enriched organic sources (compost), to guarantee the nutriment requirements and the effective use of resources.

5.8.3 Labor Requirements.

Extend and frequency of the maintenance varies deeply on the kind of Green Roof. For this case, labor could become an important barrier during the operation of the system, because knowledge on production system is required in order to provide effective actions that allows the proper growth of the plants. Plant inspections should be performed on a regular basis, therefore, the use of schedule documentation of elements (such as water quality, nutrient content, maintenance schedule) is highly recommended to identify patterns and provide effective interventions. For the case of extensive systems these activities might be reduced to the provision of nutrients, removal of intrusive vegetation, additional planting, removing dead leaves, and compensation of erosion. However, for the food production system the number of elements to consider during the operation are proportionally larger, and since the agroecological approach is proposed in this study, an understanding of the phenological stages, associability of plants, diversity of component, and a complex system understanding should be required during the operation.

5.9 Potential for synergies.

The adoption of a circular approach is relevant during the establishment of any Green Roof in order to maximize the benefits and provide affordable solutions in the use and management of resources. Based on the principles of sustainable building (Lewis *et al*, 2010), Green Roofs should be able to optimize the use of space, energy, and materials., protect and conserve the healthiness of the area, and optimize the operation and maintenance. Therefore, additional alternatives for consideration and incorporation are provided for the purpose of maximizing the benefits and expanding the lifespan of the Green Roof.

5.9.1 Organic Waste Management.

Globally one third of global food production is currently wasted, which accounts for 6-10% of human-generated greenhouse gas emissions (Gustavsson *et al*, 2011), if sustainability in urban centers is aimed to be achieved through the expanding circularity on the use of resources, **UA** provides a potential tool to reincorporate the large number of organic resources consumed in the cities, by adopting mechanisms such as separation, digestion (aerobic and anaerobic) and assimilation. The relevance for the formulation of strategies that address issues related to waste management in urban centers is constantly increasing, it has been estimated that 30 to 60% of the total urban waste is organic (Dieleman, 2017), which is a substantial amount of matter that could be used for other purposes such as agriculture.

Therefore, the expansion of alternatives such as Green Roofs can become relevant for introducing integrated safe areas, affordable, that make use of healthy processes which involve a part of circular bioeconomy. Most commonly these processes include composting, which is an ecotechnological low-cost process that allows the oxidation, degradation, and stabilization of organic waste by the action of microorganisms and for other cases by adding worms. It has also been pointed out by some studies (Goldstein, 2016, Saumel et al, 2012) that the use of compost for food production, is able to reduce pathogens-related health risk, since the metabolic process that occur are able to degrade some components.

5.9.2 Wastewater Assimilation.

As previously mentioned, **UA** provides a holistic alternative for the integration and maximization in the use of resources which involves the transformation from a linear to a circular approach. Grey water represents a potential opportunity for **UA** because it accounts approximately for 65-90% of the domestic wastewater production (Katukiza *et al*, 2014). Furthermore, gray water that comes from low polluted sources (such is the case of showers, hand-basing, laundry, etc.) could become an attractive alternative for the use on green roofs since the treatment requirements are proportionally lower and could be treated with affordable and conventional methods such as filtration, sedimentation, absorption, adsorption, oxidation, and microbial assimilation.

Some recent studies have pointed out about the use of certain vegetation varieties which would allow the use of grey water directly. Studies made by Pradhan et al (2019), provided an explanatory narrative to understand the mechanisms of pollution removal in plants, media, and microbes based on the contents of gray water, as well, they provided some operational principles to be considered during the consolidation of the Green Roof. On the other hand, Francis and Lorimer (2011), have reported a variety of species which has an outstanding performance for the treatment of gray water, such as *Adiantum raddianum*, *Chrysantheium morifolium dieffenbachia spp*., *Dracaena godseffiana*, *Epipremnum aureum*, *Hedera helix*, *Marraya sp*., *Nephrolepis exaltata*, *Philodendron sp*., *Rhododendron obtusum*, *Sansevieria trifasciata*, and *Spathiphyllum maunahoa*.

Nonetheless, if strategies for waste treatment and assimilation are intended to be applied, a proper characterization of the water should be performed in order to identify the most suitable alternatives and the feasibility of the use.

5.9.3 Water Harvesting.

Access to water is constantly a limitation for a large number of food production systems, which is more evident in urban areas where the demands are constantly increasing rather for human or commercial use, to the point where extraction rates overcome the infiltration rates. That is the reason why the adoption of additional alternatives that can improve the allocation and use of water is highly relevant. Water harvesting is a feasible alternative for the incorporation in **UASLP** western campus and there is already some proposal for the transition (Picos, 2010), however, additional considerations must be made for their incorporation along with Green Roofs, and by doing so, reducing the water deficit for the university community, and contributing with additional alternatives such as hybrid food system.

Once that the site area has been selected, it is important to estimate the amount of water that could be recover by the integration of a system (which could be estimated with the level of precipitation and the runoff coefficient), followed by the transportation and storage systems. Meanwhile, the collection and transportation of water might present ad mechanically feasible, the challenge arise for the storage within the building, since it would become a relevant load contribution.

Although, adjacent buildings can provide an opportunity for this purpose without compromising the structural capacity of the building where the Green Roof is located. The additional water collected for the irrigation of the system could allow the establishment of wider vegetal varieties within the Green Roof, and by doing so, increasing the resilience of the system. However, with the purpose to maintain and guarantee the quality of the collected water, supplementary stages should be included within the roof such as a periodic maintenance, the installation of filters and the use of effective treatment systems.

5.10 The Life Cycle Assessment of green roof.

The incorporation of methodologies for evaluating the footprint of Green Roofs such as Life Cycle assessment (**LCA**) can become an effective alternative for the enhancement and collection of data. It can also provide relevant information to properly quantify the benefits that the system provides by the acquisition of inventories, which could account the energy and materials required for the operation, as well, for the disposal at the end of the productive life. On economic terms, this could also be evaluated by the estimation of return of investment (**ROI**), however, it is essential to identify the fluxes involved. **Figure 24** provides a lifecycle process of a Green Roof including the boundaries and interactions that may occur within.

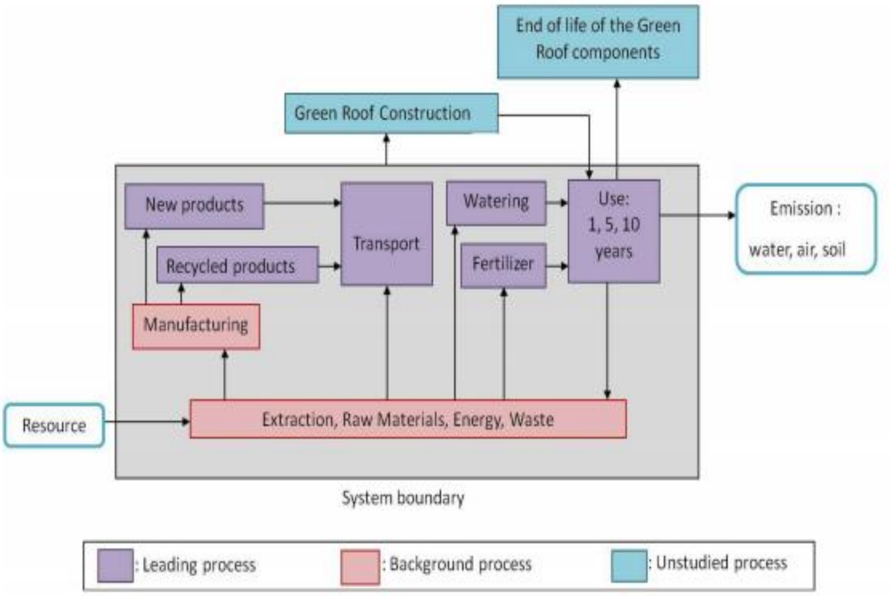

*Figure 24. Green Roof life cycle process (*Morau *et al,* 2017*).*

Furthermore, a cost comparison between conventional and green roof is usually performed in association with **ROI** of the building to determine the economic feasibility for incorporation, by instance, studies made by Kosareo and Ries (2007), found that the establishment of extensive green roofs have the potential to improve and expand the life span of a roof system to 25 years which is almost the double of a conventional roof. Some other estimations (Hamburg, 2019) point out that in terms of life-cycle cost, conventional roofs and green roofs cost about the same over a period of 40 years.

Disposal is an element that it is commonly unconsidered or avoided during the analysis of these arising technologies, nevertheless, it is important to identify the repercussions and the impacts that come along during the whole life of the green roof. Peri *et al* (2012), found that the disposal cost corresponded to approximately 4% of the total cost, where 36.1% are part of the initial capital cost and 59.3% come from the cost of maintenance. **Table 12** provides an exemplification about the benefits and barriers for the incorporation of Green Roofs.

Economic benefits	Economic barriers
Reduce energy consumption	High construction cost
Increase thermal insulation in retrofitting	High maintenance cost, especially with intensive green roofs or when irrigation is needed
Reduce maintenance costs of roof due to lengthening life	Complexity of construction
Reduce costs of water rain off and urban infrastructure	Risks of failure
Improve market and price of the buildings	Expensive integration in existing buildings if adjustments to the structure are needed
Increase usable surface of the building	

Table 12. Economic benefits and barriers for the adoption of green roofs (Berardi et al, 2014).

Nonetheless, the majority of LCA that has been performed and can be found on the literature for Green Roofs, only focus on the energy saving and construction cost that the system involves, underestimating the additional benefits (sometimes intangible) that can be achieved such as enhancement of air quality, ecosystem conservation, expanding the connectivity within green areas, and the preservation of ecosystem services. For this reason, it is relevant to enhance the formulation and incorporation of additional methodologies (such as the benefit cost analysis) that allow a proper estimation of these benefits in order to feedback on a proper manner the Life Cycle Assessment. Furthermore, the relevance for the search of possible synergies within the implementation area is essential to expand the benefits and reduce the impacts during the operation of the Green Roof.

Chapter 6

The Urban Agriculture guideline and proposal for a food security program.

6. The urban agriculture guideline and proposal for a food a food security program.

6.1 The Green Roof guideline.

Based on the principles and considerations described on the previous chapter, the following guideline was formulated with the intention to provide a sequential methodology for the formulation of a Green Roof, which would consider the following 4 stages: 1) Preliminary analysis, 2) Analysis of the location, 3) Establishment of the system, and 4) Operation and maintenance. This guideline aims to provide guidance during the decision-making process for the system, however, consideration about the elements described on Chapter 5 should be addressed in order to guarantee the effectiveness of the system.

6.1.1 Stage 1: Preliminary.

Determination of scope.

As presented along this thesis, Green Roofs can be understood and addressed from multiple approaches and purposes, and their configuration relies on the benefits and services that are intended to obtain. Therefore, determination of the goals must be considered as the basic step since it would determine the major aspects of the system such as budget, design requirements, accessibility, and performance. Hence, defining the intention of the Green Roof (rather is for food production, flood management, energy saving, recreation, aesthetic values, etc.) would establish the baseline of the system and the arrangement to fulfill the goals.

Site analysis and site location.

A proper characterization of the area should be performed (in terms of average temperatures, precipitation rates, solar irradiance and orientation, prevailing winds, exposure, among other) to be able to identify the technical and physiological feasibility for the purpose of the system, furthermore, based on this characterization, a more adequate proposal can be developed to increase the compatibility within the area, materials, substrate, and vegetation. In terms of resources management, the analysis of the area becomes highly relevant because an estimation of the requirements for the selected substrate and plants can be conducted, and by doing so, realizing about the additional inputs required.

Selection of location.

For the case of a building complex such is the case of UASLP western campus, the selection of the specific location would rely on the accessibility of the area and the effects that might take place by the surrounding buildings. By instance, these building can provide additional shading for the Green Roofs, which might affect the healthiness of the system, they could also diminish the exposure to wind and rain. On the same direction, some buildings can provide additional reflection (mainly due the characteristics of the materials) and amplify the intensity of the sunlight, which could become a limiting aspect for vegetal growth. Therefore, the selection of the site should consider these aspects prior moving forward with the mechanical feasibility.

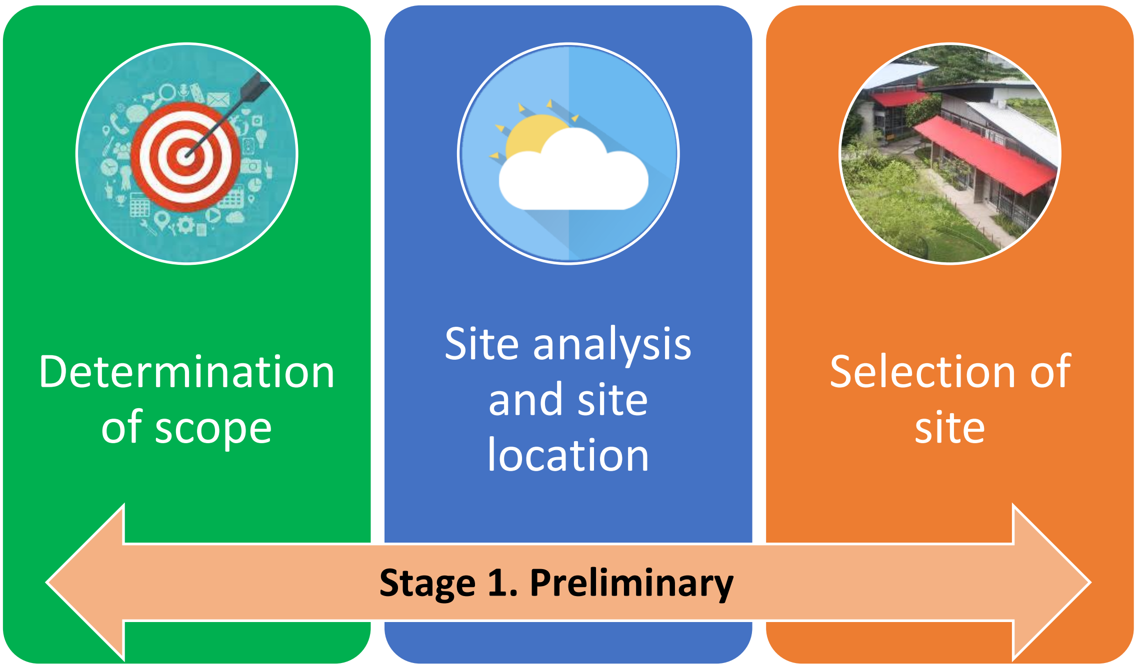

Figure 25. Preliminary stage.

6.1.2 Stage 2: Analysis of location.

Structural Capacity.

Once that the implementation area has been selected, a structural integrity evaluation must be performed to determine the feasibility of the roof according to the purposes that area intended, and the implications involved (such is the depth of the substrate and the variety of plants). For the cases where the roof does not posses the structural capacity for the kind of Green Roof that is expected, a retrofitting or reinforcement should be considered as mandatory.

The determination of the load capacity for the building involves a combination of living and dead loads for the system, therefore, it should include: the layers of the system (waterproof, anti-root, drainage layer, filter layer), saturated growing substrate, plant weigh at a maturity stage, and the weights involved during the construction, operation, and maintenance activities. On a responsive approach (which sometimes becomes the starting point of the project when reinforcement of the building is a limiting factor), the load capacity of the building is the one that determine the function, accessibility, kind of substrate and plants, and the strategies for the operation and maintenance.

Furthermore, as proposed on Chapter 5, a hybridization of the system can be achieved by the alternation of the kind of use (from intensive, semi-intensive, and extensive) within the system according to the loading capacity of specific areas. The use of local buildings and construction regulations can be adopted as a preliminary guidance for the determination of the load capacity for the buildings.

Slope.

The capability of retention and disposal of water is something that should be optimized within the system in order to guarantee the most suitable conditions for vegetation growth, which at the same time would allow a proper performance of the Green Roof. Which is why, a proper establishment or adequation of the slope should be performed. For the case of flat buildings (which is the main configuration for the Green Roofs), actions should be taken to facilitate a proper drainage. According to the relevant data at the moment, 2% of slope should be considered as the norm for extensive and intensive Green Roof since this gradient is enough to provide an effective drainage and avoid losses of water. For the cases where higher gradients of slope are unavoidable, special structures (modular systems) that allow a high-water storage capacity and poor drainage should be considered in order to compensate the higher gradient.

Access to services.

Green Roofs are complex systems that require a constant allocation of resources and tracing, hence, allowing a convenient access for the people and services is something that should be considered during this stage. In terms of access for the people, the most common alternative are elevators and stairs, however, synergies with the adjacent buildings can be created to facilitate the access. Furthermore, the establishment of the required pipelines and equipment for irrigation, as well for the electrical facilities for maintenance and operation, must be guaranteed and meet the safety standards of the area.

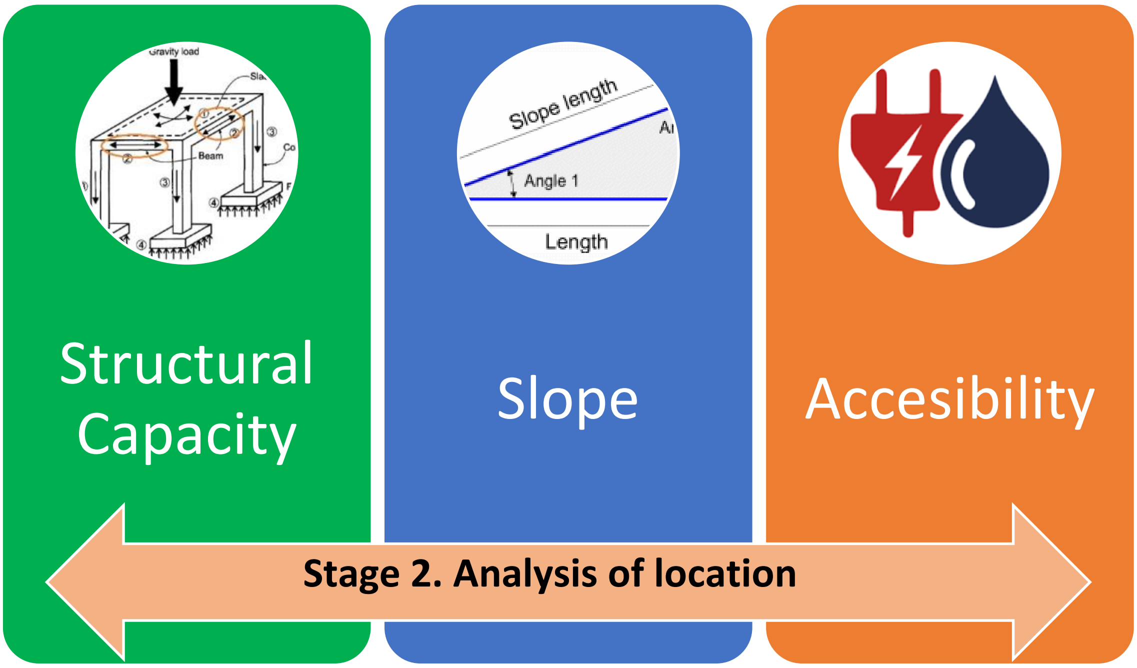

Figure 26. Analysis of the location.

6.1.3 Stage 3: Establishment.

Layering.

The effectiveness and performance of a Green Roof relies deeply on the synchrony and compatibility of each one of the layers. Therefore, an informed decision about the technical capability of each one of the materials selected must be made for each one of the layers in order to fulfill the goals intended. For this section, the layering goes as follows: a) Waterproof membrane, b) Anti-root membrane and protection layer, c) Drainage layer, and d) Filter layer. The first section is composed by the waterproof membrane which would be the one in charge of preventing inputs in the building, and the most common materials adopted are modified bitumen, thermoplastic membranes of polyvinyl chloride, elastomeric membranes, etc. However, this selection could be based on the climate conditions of the area and the market availability.

Anti-root membrane is the section in charge of avoiding the entrance of plant roots to the underlying layers and provoke disturbance in the system and requires a thickness of 0.8mm according to international standards., and the most common materials are hard plastic sheets (such as polyethylene and PVC), or metal layers impregnated with copper hydroxide. Nonetheless, this selection would depend on the requirements of the specific system and the budget itself.

Drainage Layer comes after and it is highly relevant since it can provide an adequate distribution of air and water for the substrate and the plants, at the same time, it is able to act as a water reservoir during stress periods. For this layer the most suitable configuration is the use of granular materials or modular panels as referred and described deeply on Chapter 5.

The final element of this conjunction is the filter layer, which is included to become a barrier between the substrate and the lower layers and by doing so, avoiding the entrance of small roots or particles to the drainage layer, and creating a clog. For this layer, geo-textiles are the most common materials adopted since they are able to retain some water, furthermore, some additional additives can be found on this layer to avoid the expansion of aggressive roots.

Substrate.

During the determination of the scope of the Green Roof, special consideration should be made to provide an adequate substrate with the conditions required. Therefore, it is highly recommended to specifically formulate the growing medium according to the kind of system. On general terms in can be mentioned that the following features should be achieved: a) adequate organic matter, b) high water holding capacity, c) high hydraulic conductivity, d) low bulk density, e) high sorption capacity, and f) durability.

Plants.

The selection of plants would depend on the goals that are intended, and their selection should include an analysis of compatibility within layers and the building itself. The previous chapter provides a list of criterions that could be included during the selection of the species, as well, it provides a proposal of plants for each kind of roof. Nonetheless, a high level of compatibility between the substrate and the plants is essential to guarantee the durability of the living media.

Figure 27. Establishment of the system.

6.1.4 Stage 4: Operation and Maintenance.

Watering.

The fact that Green Roofs are artificial environments that might not posses the adaptability and resilience of the natural system that intent to mimic, implies that a constant supervision and allocation of resources is necessary. For the case when a food production system is indented to be implemented as this study suggests, the necessity of an adequate irrigation system is more relevant to guarantee the basic requirements that allow the maximum vegetation growth.

The most largely adopted irrigation types for Green Roof are overhead spray, drip, hose bib and capillary. Nonetheless, the periodicity and intensity of the irrigation would depend on the scope for the area, and the selected species. Drip irrigation could become a feasible alternative in areas where high losses of water are expected (associated with the irradiation levels), although, a lateral and vertical flow capacity within the substrate must be achieved. Besides, in order to improve the procedures of irrigation and conserve water, additional monitoring equipment such as timers, flow metes, runoff monitors and sensors can be included, although, they usually involve high capital investments.

Fertilizing.

Fertilization is something essential to consider during the implementation of the Green Roof and their following operation to enable a healthy environment. Consideration about the macro and micronutrients required for the plants would determine the periodicity of fertilization, as well, as the type of fertilizer. For the case of extensive green roofs, it is recommended to maintain the level of fertilization on very low levels in order to avoid growth of invasive plants, nonetheless, for the food production systems this limitation is excluded due the larger organic requirements. The possibility for synergies (such is the case of waste management) is highly recommended as showed on the previous chapter.

Follow-up.

Due the high level of complexity and the large number of interconnected variables within the system, a formulation of a monitoring and tracing plan is essential in order to keep record about the process and interactions, and by doing so, providing preventive and effective measures. Among the elements that should be considered for tracing and supervision are the following:

- Quality of water and organic materials for fertilizing.
- Inspection and maintenance for vegetation on daily basis.
- Compensation of substrate losses due wind effect.
- Removal of foreign vegetation for the extensive areas.
- Maintenance of the equipment and irrigation system.
- Monitoring for root penetration and leakages.

Figure 28. Operation of the system.

6.2 Food security strategy.

The metabolism analysis of a system is able to provide relevant aspects about the dynamics, conditions and phenomenon that take place within, as well to understand and explain the possible causes behind the interconnections and responses of the elements. The analysis of the urban metabolism in the **MASLP** and the introductory policy analysis based on the **MUFPPMF** that were performed, provided relevant information about the food challenges that are currently taking place within the limits of the city, and with that involving the university community.

In a country where high levels of inequality, poverty, food insecurity and environmental degradation are dominant, the formulation of mechanisms that allow actions for mitigation and alleviation of these conditions are highly relevant and required. The Autonomous University of San Luis Potosi who among their principles are the social fulfillment and the seek of welfare, they can become the pilot that allows and create the opportunities to overcome this situation on the local scale.

This has been mentioned, and has become the principles during the formulation of the project "Uni Huerto" and "Uni Techo Vivo", which have collaboratively worked with thousands of people for building capacity and self-sufficiency, nonetheless, a proper strategy for the expansion is required through the collaboration between the sectors of the society., a food security strategy that delivers food security and nutrition for the community in a respectful, inclusive, and reciprocal way with the surroundings.

The adoption of tools such as the **MUFPPMF** can be incorporated for the formulation of strategies and frameworks that address these issues, as well for the further tracing and evaluation. Based on their outcome areas, the establishment of institutions (such is the case of councils) with the ability to act can become necessary for the promotion of sustainable diets, enhancement of the social and economic condition by expanding the food production, and by reducing the effects associated with food waste.

The incorporation and evaluation of the indicators of the **MUFPPMF** for the food strategy can provide relevant information about the critical aspects on each one of the outcome areas, and by doing so, being able to elaborate/apply multifactorial and effective interventions. Therefore, according to these goals, the current issues, challenges, and condition for the **UASLP** western campus, the proposal of an adequate food security strategy should stablish the following goals:

- Achieve food security for the most vulnerable members of the university community.
- Development of comprehensive and sustainable models for food production based on the incorporation of unused areas.
- Enhancement and expansion of local food production based on the agroecological principles.
- Creation of partnerships with the relevant actors of the food system who sympathize to these principles.
- Formulation of policies addressed to improve the nutritional environment.
- Formulation of policies, programs or plans addressed to enhance the circularity on the use of resources, and reduction of food waste.

6.3 Food policy initiative.

The achievement of autonomy from part of the university has come from a complex historical process of ideological struggle, where the institution has gained the ability of action and self-determination from the state. This autonomy involves the capability for the establishment of the principles and the bases for operation in terms of regulation, education, and administration.

Based on the principles, vision and goals stated on the institutional development plant, the institution is compromised to contribute with the formulation, application and promotion of solutions for the problems local, nationally and globally trough the collaboration with the society in an inclusive, equitable, and responsible way, whereby, this autonomy can allow the adoption of the good practices performed on previous years such is the case of the **UA** incorporation on unused areas such as rooftops, and their transformation into policies that could become an expansible initiative for a larger scale.

During the development of this thesis, the multifactorial analysis and description of the UA approach has showed its relevance, the compatibility for integration, and the potential contributions than can be achieved if the proper mechanisms are created. Therefore, a policy formulation that details the operational framework which includes the goals, principles, responsibilities, and operational guidelines is essential in order to provide effective actions towards the food security status.

Nonetheless, for the case o a food strategy and the further formulation of policies, a capable institution with ability to act, aware about the conditions and challenges within the campus is required to determine the framework and principles for operation.

Agenda Ambiental is one of the institutions which has constantly worked in collaboration with the university faculties through their environmental management system, promoting the transformation of practices towards achieving sustainability for the campus., which now is currently working on the formulation of programs addressed to water and energy management, as well as the expansion of green areas.

The role of Agenda Ambiental towards enhancing the food security for the university community can be compared to the role of the Food Policy Councils, which are the institutions in charge for the promotion of solutions that enhance the local food systems, through the formulation of policies and programs focusing on advocacy and civic engagement, networking and partnering development, equity, inclusivity, and education., having as a reference the implications of the food system and the scope that the effective actions might have on the social and political dimension within implementation area.

Therefore, Agenda Ambiental can become the institution in charge for the formulation of these policies, which can make use of the urban metabolism approach to estimate, evaluate, and understand the requirements and deficiencies in terms of Water-Food-Energy, in order to define the goals and principles during the formulation of policies. As well, for the use frameworks such as MUFPPMF that provide the mechanisms for the evaluation towards the establishment and following of these policies.

During Chapter 5 and 6 of this work, it has been mentioned about the feasibility for integration of UA within the rooftops of UASLP western campus, furthermore, a comprehensive description of the components of a Green Roof (either for food production or not), and an implementation guideline was formulated with the intention to be incorporated on the future policies for the university, as well, as an instrument that can be adopted, interpretated, and extrapolated for any other UASLP campus.

Nevertheless, the creation of an effective framework that allow the allocation of resources, the establishment of instruments that enhance the participation, the creation benefits (economic and social), and the designation of responsibilities is essential to guarantee the effectiveness of the future policies and create substantial benefits for the university community.

For these reasons, for the formulation of a university food policy that aims to enhance the local environment by the creation of green spaces for food production, which are able to contribute to the food security of the university community, the elements that should be considered are the following.

- Definition of the long-term goals that are intended by the creation of Green Roofs on each one of the possible configurations.
- Designation of responsibilities for the institutions and departments in charge for the planning, establishment, and operation of the systems.
- Estimation about the possible food production according to the structural capability of the area, and the access to resources.
- Delimitation of criterion for the selection of the destination for the food production. For the case of a food program for students, a concise and adequate plan that allows the most vulnerable members of the community to become beneficiaries must be detailed.
- A technical implementation guideline that defines and describes properly the terminology and the procedures for the establishment and operation of Green Roofs.
- Definition of tools for the analysis and evaluation of the actions (such is the case of the operationalization of indicators from the **MUFPPMF**).
- Definition and introduction of alternatives that allow the maximization on the use of resources within the **UASLP** western campus, in terms of reducing food waste by promoting the principles of circularity.

Chapter 7

Conclusions.

7. Conclusions.

The concept and implications for the incorporation of food production systems within urban centers were analyzed and reviewed during this thesis, hereby, it is presented as a feasible alternative able to contribute to the food security of the population, improve their nutritional condition, increase social participation, mitigate the effects of climate change, and provide mechanisms that allow circularity on the use of resources. Additionally, this thesis made an introductory systemic analysis about the economic and political conditions that have prevailed during the urbanization process in Mexico with a deeper emphasis on the Metropolitan Area of San Luis Potosí.

The urban metabolism approach that was conducted on Chapter 3 for the **MASLP** and the **UASLP** western campus, provided relevant quantitative data regarding the use and management of resources. For the case of the **MASLP**, one of the main identified issues are the massive amounts of water losses caused by leakages which accounts for the same amounts use for industrial and agricultural users. Additionally, rainwater represents an important underused resource that could cover all the domestic demand with less than 20%, at the same time, the lack of infrastructure and the severity on climate events is increasing the risk for the area. Therefore, the adoption of alternatives able to mitigate these aspects (such as Green Roof urban agriculture) are highly required, whereby, this chapter contributes with an estimation of the total roof surface and their spatial distribution according to the type of land use, with the intention to be incorporated on future proposals. Finally, for the case of the western campus, it was found that there is a deficit of green areas for the university community, and an estimation of the total roof area was performed with the intention to provide an alternative for the introduction of additional green spaces.

Based on the explorative and narrative approach that was performed making use of the **MUFPPMF** on Chapter 4, it was found that a large sector of the food system has been transformed since the 1990 decade where the liberalization policies took effect within the country, this has accelerated the migration process for the farming community who besides from being already on a situation of scarcity, they were unable to compete with large subsidised and expansive agricultural sector. Ever since then, the urbanization process increased massively in the country and with that, the lifestyle and consumption patterns of the society. The change on dietary patterns can be associated with the large availability of processed food with high caloric content and low nutritional value, and the tendency for their consumption on the urban centers, to the point where Mexico has one of the highest obesity rates in the world, and the prevalence of diet related diseases (such as diabetes, hypertension, cancer, etc.) are on the rise. On the same line, it was reported by the interviews performed, how the lack of policies and incentives for small produces are accelerating the centralization of the food system, to the point that has become a thread for the preservation of the local farming communities and their diversity. Another relevant aspect that was found during the study refers to the food waste that is currently taking place within the area, and the lack of strategies for the proper management that could improve the food security of the population.

Since the primary objective of the study is the formulation of a Green Roof urban agriculture guideline that can be incorporated on strategies for the university community, Chapter 5 provides a description of the most relevant aspects and criterions to consider during the analysis, design, and establishment of a Green Roof which include the structural analysis, layering, substrate and selection of plants., as well, it provides relevant information about the latest findings on the literature referring to each one of the components. Based on these blocks, Chapter 6 contributed with descriptive guideline that involves each one of the major aspects, steps, and alternatives for the implementation of a Green Roof. If UA is intended to be introduced as a mitigation alternative for the failures and issues in urban centers, strategies and policies must be formulated and implemented properly, therefore, some of the principles for a food strategy were stipulated, in addition to an introduction of the components that should be considered during the formulation of policies for the University Autonomous of San Luis Potosi, which can become a pilot project with potential for further expansion.

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