

Sustainability of the Agri-food System's Characterization with Food Sovereignty Framework and the Evaluation Approach of the Major Threats.

Caracterización de la Sostenibilidad del Sistema Agroalimentario en el Marco de la Soberanía Alimentaria y Aproximación a la Evaluación de sus Principales Amenazas.

Caracterització de la Sostenibilitat del Sistema Agroalimentari en el Marc de la Sobirania Alimentària i Aproximació a l'Avaluació de les seves principals Amenaces.

PhD in Sustainability

Research Proposal

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Abstract

A series of international events —food crises, food price volatility, shortages, famine, land disputes— have put into question the efficiency of the agri-food system to reach its main goal: the food security for its entire population (Ericksen, 2008). A particular problem constraining the achievement of this goal is the inherent complexity the agri-food system, which couple with its continuous evolution difficult the assessment of the system itself, and renders international comparison incomplete. This posits the question of how to reach system sustainability. In my doctoral research I strive to contribute to this specific field by developing a framework of key parameters that may allow characterizing the degree of global sustainability of the global agri-food system, throughout the study and analysis of its agents, interactions main strengths and vulnerabilities. As a preliminary study I conducted a conceptual analysis of four relevant paradigms that have emerged in opposition to the current production logics: Food Security, Sustainable Agriculture, Agroecology and Food Sovereignty. Through this analysis I found that the concept of Food Sovereignty pursues a less vulnerable agri-food system from an agroecological perspective, and thus renders a more complete view. From here on, my research will seek to provide a quantitative framework to evaluate whether such paradigm has indeed the capacity to offer a sustainable system of agri-food production. The framework is grounded upon a set of indicators that allow cross-countries comparison, and has its origin on the work performed previously by Ortega-Cerdà and Rivera-Ferre (2010). In this document I present my research proposal, by which I detail the steps, methodology and current progress.

Key words: *sustainability, agri-food systems, food sovereignty, food security, agroecology, biofuels, agriculture, rural development, gender equity, indicators.*

Resumen

Una serie de eventos internacionales –crisis alimenticias, la volatilidad de precios de los alimentos, la escasez, el hambre, la disputas por la tierra– han puesto en duda la eficacia del sistema agroalimentario para alcanzar su principal objetivo: la seguridad alimentaria de la población (Ericksen, 2008). Un problema particular que limita la consecución de este objetivo es tanto la complejidad inherente del sistema agroalimentario como su continua evolución, que a su vez dificulta la evaluación del propio sistema y hace que la comparación internacional incompleta. Esto plantea la cuestión de cómo llegar a la sostenibilidad del sistema. En mi investigación doctoral me esfuerzo por contribuir a este campo específico mediante el desarrollo de un marco conceptual de parámetros clave que permitan caracterizar el grado de sostenibilidad global del sistema agroalimentario mundial, a través del estudio y el análisis de sus agentes, las interacciones principales fortalezas y vulnerabilidades . A manera de estudio preliminar, realicé un análisis conceptual de cuatro paradigmas más relevantes que han surgido en oposición a las lógicas de producción actuales: Seguridad Alimentaria, Agricultura Sustentable, Agroecología y Soberanía Alimentaria. En dicho análisis encontré que la Soberanía Alimentaria persigue un sistema agroalimentario menos vulnerable desde una perspectiva agroecológica, y por lo tanto representa una visión más completa. A partir de ahí, mi investigación busca proporcionar un marco cuantitativo para evaluar si tal paradigma tiene de hecho la capacidad de ofrecer un sistema sostenible de producción agroalimentaria. El marco se basa en un conjunto de indicadores que permitan la comparación entre países, y tiene su origen en el trabajo realizado previamente por Ortega-Cerdà y Rivera-Ferre (2010). En este documento presento mi propuesta de investigación, detallando los pasos, la metodología y el progreso alcanzado a la fecha.

Palabras clave: *sostenibilidad, sistemas agroalimentarios, soberanía alimentaria, seguridad alimentaria, agroecología, biocombustibles, agricultura, desarrollo rural, equidad de género, indicadores.*

Resum

Una sèrie d'esdeveniments internacionals -crisi alimentàries, la volatilitat de preus dels aliments, l'escassetat, la fam, la disputes per la terra- han posat en dubte l'eficàcia del sistema agroalimentari per assolir el seu principal objectiu: la seguretat alimentària de la població (Ericksen, 2008). Un problema particular que limita la consecució d'aquest objectiu és tant la complexitat inherent del sistema agroalimentari com la seva contínua evolució, que al seu torn dificulta l'avaluació del propi sistema i fa que la comparació internacional incompleta. Això planteja la qüestió de com arribar a la sostenibilitat del sistema. En la meva recerca doctoral m'esforço per contribuir a aquest camp específic mitjançant el desenvolupament d'un marc conceptual de paràmetres clau que permetin caracteritzar el grau de sostenibilitat global del sistema agroalimentari mundial, a través de l'estudi i l'anàlisi dels seus agents, les interaccions principals fortaleeses i vulnerabilitats. A manera d'estudi preliminar, vaig realitzar una anàlisi conceptual de quatre paradigmes més rellevants que han sorgit en oposició a les lògiques de producció actuals: Seguretat Alimentària, Agricultura Sostenible, Agroecologia i Sobirania Alimentària. En aquesta anàlisi vaig trobar que la Sobirania Alimentària persegueix un sistema agroalimentari menys vulnerable des d'una perspectiva agroecològica, i per tant representa una visió més completa. A partir d'aquí, la meva investigació busca proporcionar un marc quantitatiu per avaluar si aquesta paradigma té de fet la capacitat d'oferir un sistema sostenible de producció agroalimentària. El marc es basa en un conjunt d'indicadors que permetin la comparació entre països, i té el seu origen en el treball realitzat prèviament per Ortega-Cerdà i Rivera-Ferre (2010). En aquest document presento la meva proposta d'investigació, detallant els passos, la metodologia i el progrés assolit a la data.

Paraules clau: *sostenibilitat, sistemes agroalimentaris, sobirania alimentària, seguretat alimentària, agroecologia, biocombustibles, agricultura, desenvolupament rural, equitat de gènere, indicadors.*

1 Introduction

The agri-food system^{1,2} encompasses the productive chain up to food consumption, colloquially known as the process “from field to plate” (Ericksen, 2008). This system is constituted by various subsystems of diverse scales in which several agents and factors interact depending on the environmental, social and economic contexts that are at place. For instance, the set of subsystems may vary depending on the type of food that is being produced, the climate, and the local culture among other factors that influence the productive chain across both temporal and generational scales.

The main objective of the agri-food system must be to attain food security for its population (Ericksen, 2008), this is to say that the system must ensure that “every person, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life (World Food Summit, 1996).”³

With this in mind it should be possible to set the parameters to assess whether the agri-food system goal is being effectively achieved. Nevertheless, given its complexity and continuous evolution, its assessment is open to subjective interpretations and thus remains a highly politicized topic (McMichael, 2007).

In addition to this, there are a series of secondary objectives that can be derived from the main objective mentioned above. These objectives have been driven to a great extent by global market needs rather than by the necessities of the local populations, and hence increase the risks for the proper fulfillment of the original agri-food system goal. Among these secondary objectives stand out the production of energy (agrofuels⁴), the feeding of cattle, and the generation of economic

¹ A system is defined by the set of interactions that maintain its parts (either components or agents), and by the consequences arising from such interactions (see <http://www.systems->

² For the interest of this work the agri-food system is viewed as pertaining to both the “agri-food system” and the “food system”, even though the latter concept would not contemplate the agricultural side for certain authors.

³ <http://www.fao.org/organicag/oa-specialfeatures/oa-foodsecurity/en/>

⁴ Biofuels are fuels derived from biomass like wood, plants and manure, which have been used historically for producing heat, light and electricity among other necessities. Agrofuels, particularly, are biofuels coming from agricultural products like bioethanol or biodiesel, these fuels are now the center of two major debates: the

wealth through both regulated and unregulated (price speculation) markets. This offers a plausible explanation upon why in a world where food is produced in abundance where the Gross per capita Production Index Number in Agriculture has continuously growing over the past decades (Figure 1), hunger and undernourishment still affects hundred of million people worldwide every year.

Governmental bodies as well as private firms tackled this problem with greater investments, greater food production and a wider opening of food markets, given their expectancy that in spite of the external constraints (i.e., climate change) and population growth rate, there would remain decades of inexpensive food production (IPCC, 2007; Soussana, 2014). Empirical evidence, however, suggests that in time these measures have aggravated the problem rather than mitigated it; in the last years historical levels of undernourishment and the loss of natural resources have been reached.

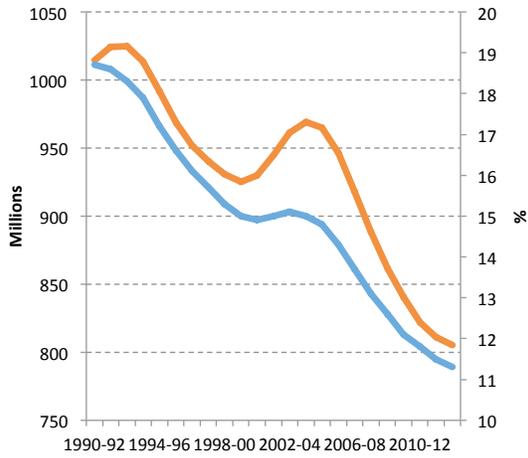
During the World Food Summit, held in Rome back in 1996, there was an agreement to reduce in one half the number of people suffering from hunger in the world. However, with a few months to reach the stipulated term for achieving this goal, the Food and Agriculture Organization (FAO) has estimated that, despite of the reduction of 173 millions people from 1990-1992 to 2011-2013 that suffered from chronic hunger (UNDP, 2014), one over eight people in the world still suffers from chronic undernourishment (Ballard, Kepple, & Cafiero, 2013). Although the population below the minimum level of dietary energy consumption has drop since 1990, still is more than 11% of the world population (Figure 1).

Moreover, in recent decades, chronic hunger has shown significant volatility mainly due to global market conditions (GRAIN, 2008). According to GRAIN this phenomenon suggests that in recent decades hunger has been adopted as a means for political negotiation by different markets.

first relates to the ethical question on whether food, which could well shoveling the problem of hunger in the world, should be used to produce energy. The second refers to whether energy generation by means of biofuels is indeed more sustainable and resource efficient than alternative sources of energy. Many authors have analyze this (Giampietro & Pimentel, 1993; Patrick, 2011; Pimentel, 2008; Raman & Mohr, 2014)

Figure 1 - Undernourishment and Food Production

Number of people undernourished (orange, right axis)
& Prevalence of undernourishment (blue, left axis)



Source: FAO – Food Security Statistics

Gross per capita Production Index Number in
Agriculture (2004-2006 = 100)



Source: FAO – FAOSTAT

Hunger and undernourishment are not the only problems that the current agri-food model faces. Environmental damage caused by agricultural activities is also a constant threat; both for present needs as well as for the sustainability of the system in time, particularly under the uncertain consequences of climate change.

In 2009, FAO reported that the intensive agricultural model⁵ has caused the loss of almost 70 percent of agricultural soil (Figure 2) and that 80 percent of new agricultural fields are been taken from tropical forests, severely affecting the existing biodiversity as well as some key environmental services in the tropics (Foley et al., 2011).

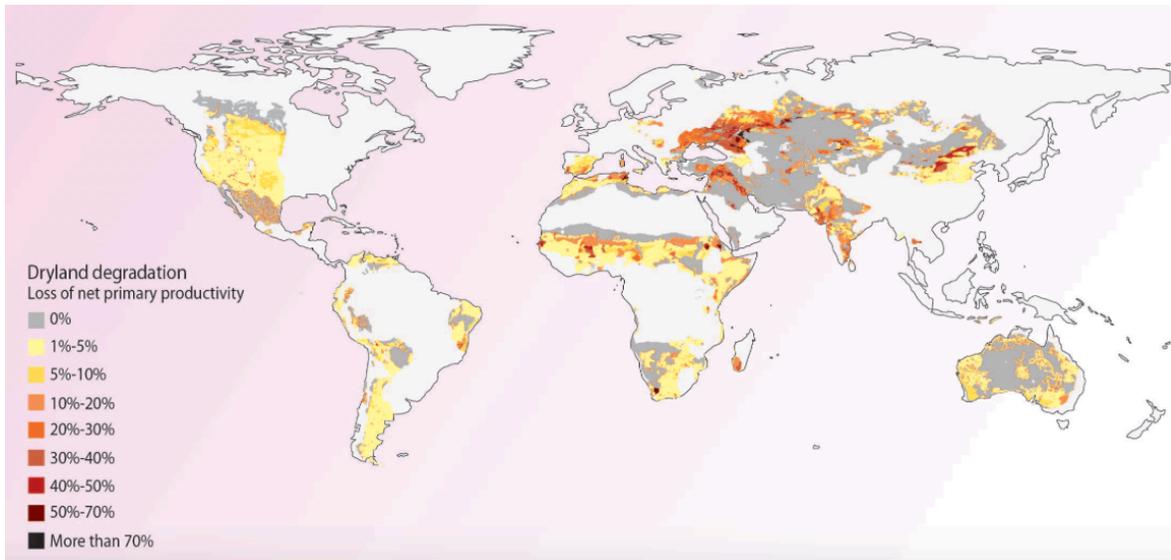
In addition to this, rural society has had to deal with the erosion of agricultural soil pertaining to small producers who attempted to follow the agricultural boom and ended up either losing their lands because of the excessive use of chemicals purchased from big enterprises or their land productivity against bigger competitors⁶; a situation that favored the concentration of agricultural

⁵ The intensive agricultural model refers to that in which there exist an indiscriminate use of fertilizers and pesticides.

⁶ Land productivity is measured as a single crop produced per hectare. Alternative measures of productivity such as the amount of necessary resources (water, energy, and so forth) would imply even lower levels of productivity.

soil and consequently of economic benefits coming from rural fields, hence threatening the long term survival of small agricultural producers⁷.

Figure 2 – Land degradation results in decreasing agricultural productivity



Source: (Zika & Erb, 2009)

Currently, there is an ongoing debate in the agri-food system between those who want to strengthen what McMichael (2009) characterizes as the corporate food regime⁸ and those who propose alternative production routes (as explained in Section 2). The former group is constituted by governmental bodies, global institutions, monopolies of the agri-food industry, universities, think tanks, and philanthropic organizations. In spite of social and environmental critics, these actors have proposed a so-called “green revolution”⁹ as a solution to hunger and rural poverty. Their

⁷ According to a declaration from the Asian NGO and SCO in the World Food Summit (Kathmandu, May 2002).

⁸ “A food regime is a temporally specific dynamic in the global political economy of food. It is characterized by particular institutional structures, norms, and unwritten rules around agriculture and food that are geographically and historically specific” (Otero, Pechlaner, & Gürcan, 2013). McMichael name the current dominant production and consumption structure at global scale as de corporate food regime (Holt-Giménez & Altieri, 2012; McMichael, 2006). The corporate food regime is “a relatively stable set of relationships privileging corporate agriculture, in the service of capital accumulation on a world scale and at the expense of smallholder agriculture, local ecologies and ‘redundant’ urban fringe-dwellers” (McMichael, 2009).

⁹ The term Green Revolution refers to the international movement promoted in by the mid of XX century, that incorporates changes to the traditional agricultural model with the aim of increasing agricultural production.

strategy is centered in a greater production of essential food to achieve food security, for which they incentivize the use of biotechnology and genetically modified organisms (GMOs), as well as a greater opening to global markets (Holt-Giménez & Altieri, 2012). Conversely, certain social civil organizations (SCOs) together with non-governmental organizations (NGOs) propose local perspective alternatives. This is to focus production from farmers that are aimed at the sustainability of the agri-food system. Some of these alternatives are intended to change the existing paradigm and return to the traditional roots of farming and agricultural production.

1.1 Agri-food System Analysis and Its Complexity

Current literature with regard to agri-food systems proposes divergent perspectives to its analysis. Traditionally, the bulk of studies centered along food supply chains where scholars attempted to develop simple theoretical models to find universal solutions on public policies that frequently failed (Ostrom, 2009). However, in recent time, variables that delve into details of distribution, access and usage (consumption) of food have gained relevance, and enhanced the scope of study.

In order to define the agri-food system, Ericksen (2008) proposes that a wide definition should include:

- i. Interactions between and within biogeophysical and human environments (the relationship between the human being and its environment) that shape the bulk of activities.
- ii. The set of such activities comprised from food production to food consumption.
- iii. The expected results from those activities, like their potential contributions to food security, environmental security and social welfare.
- iv. Any other determinant of food security.

Such changes are focused in the mass use of fertilizers, pesticides and herbicides, genetic modification, implementation of artificial irrigation systems that allow intensive exploitation of soil, and the production at large scale of a single crop.

The previous scheme contemplates human food as the main emerging property of the system. This is to argue that the system should utilize its resources for the goal of human nutrition, which is what Ostrom (2009) perceives as a complex socio-ecological system (SESs)¹⁰.

Ostrom (2009) proposes that in order to understand a SES it is indispensable to first know its specific components and how these interact against each other. The agri-food system involves complex interactions amongst agricultural, environmental and socio-economic systems that are heterogeneous in time and space and multidimensional in nature (Vallejo-Rojas, Ravera, & Rivera-Ferre, 2013).

Ericksen (2008) proposes a reference framework for the study of such interactions in which there exist an implicit recognition that such systems are managed (either directly or indirectly) for the human benefit (i.e., ecosystem services) and that a set of services could be favored (food production, for instance) at the expense of other set (quality of water for fish) and that these objectives can hence conflict to each other. Throughout this framework food security and sustainable environmental management are pursued.

The framework proposed by Ericksen (Figure 3) contemplates four main activities that take place within the system:

- i. Food production;
- ii. Packaging;
- iii. Distribution and sale, and
- iv. Consumption.

The first activity includes all the processes that are intrinsically related to raw material production, those related with agriculture and animal breeding. The second one incorporates those activities related to raw material transformation. The third, distribution and sale, considers such activities through which food is moved from a place to another. Finally, consumption refers to those activities that range from food selection to its cooking and final consumption.

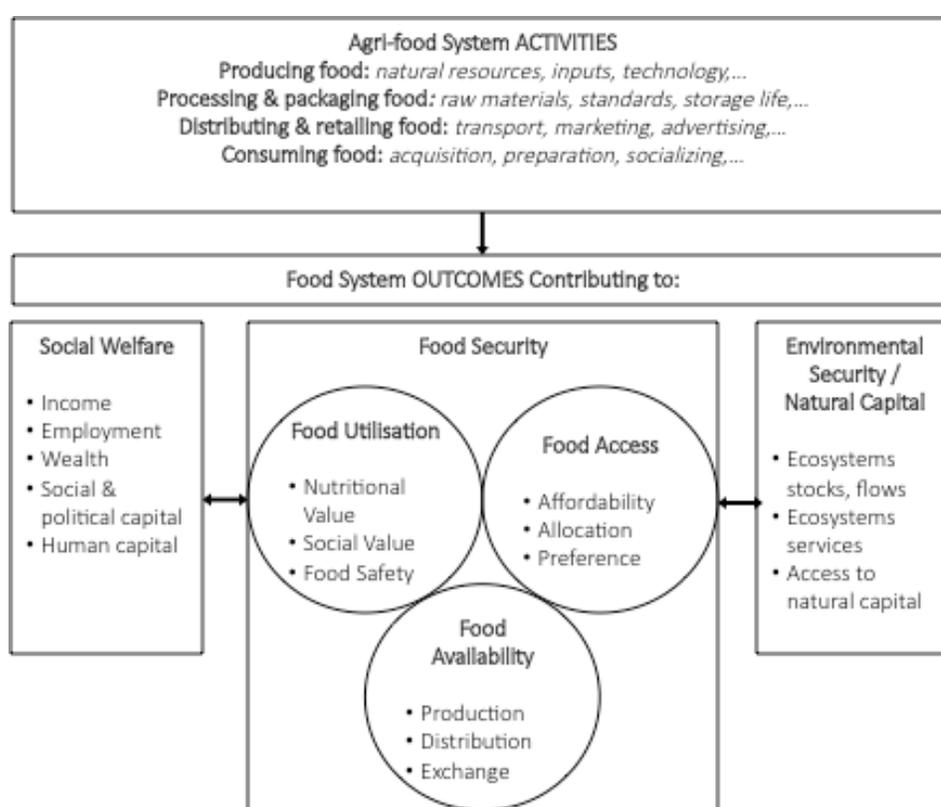
The final expected result from this framework would be a benchmark to measure food security in terms of access, availability, and usage. Access would refer to the ability from a unit to get a hold of

¹⁰ A SES is a complex system composed by multiple subsystems and internal variables which are relatively detachable but that remain interacting, generating consequences at the SES level which are later on fed back and affect the subsystems and their components.

food in with the quality and quantity required. Availability makes reference to the quantity, quality and type of food that a unit has at its disposal. Usage, in turn, deals with the household capacity to benefit from food consumption.

According to this author, the aforementioned agri-food activities (Figure 3) not only contribute to achieve the ultimate goal of food security, but also to the population welfare and the safety of the environment. Nonetheless, these contributions are recognized as secondary results that may or may not be achieved.

Figure 3 – Components of the Agri-Food System (Adapted from Ericksen (2008))



Vallejo-Rojas, Ravera and Rivera-Ferre (2013), in turn, have proposed a framework that incorporates socio-economic, politic and environmental aspects into the analysis of the agri-food system. These authors center their study in the framework initially put forth by Ostrom, in which SES is shown as a complex system that may be detached into subsystems that are dynamic in themselves but still affect the processes that take place at the SES level.

Within this framework, the authors link the four activities suggested by Ericksen with five pillars of Food Sovereignty which constitute the basic benchmarks for a sustainable agri-food system:

- Pillar 1: access to resources;
- Pillar 2: production models;
- Pillar 3: transformation and commercialization;
- Pillar 4: consumption and nutrition rights, and
- Pillar 5: agricultural policies (See section 2.4) (Table 1).

Table 1 – Relation among activities, actors and expected results

Agri-food activities	Key actors		Potential outcomes
Producing food	Farmers, multiple suppliers of production inputs (including agricultural laborers and land owners), and organizations that establish and monitor the production.		Right to food
			Access to productive resources
Processing and packaging food	Farmers that transform their raw, products middlemen, owners and managers of processing plants, regulatory bodies established to control quality and safety food.	Food Sovereignty	Production model
			Trade and local markets
			Agrarian policies
Distributing and retailing food	Farmers that sell their products, in formal networking organizations to distribute and sell, middlemen, governmental and municipal authorities.	Food security	Food availability
			Food access
			Food utilization
Consuming food	Consumers. Includes people that obtain food through food purchase, subsistence agriculture, and through other means such as informal social arrangements for barter and food aid.	Other societal interests	Social welfare
			Environmental welfare

Source: Adapted from Vallejo-Rojas et al. (2013)

This research proposal is structured as follows: The following section describes the conceptual analysis that have been undertaken thus far, it also identifies three key threats that may endanger the current model of food production. Section three puts forth the motivation and expected contribution of this PhD thesis, as well as the objectives and the limitations of this research. Section four describes the methodology. Finally, section five presents the PhD's timetable where the level of attained progress is described.

2 Conceptual Analysis

Arguably, the study of the agri-food system can be tackled from four main perspectives:

- From a food supply perspective, by which access to food suitable for consumption is pursued.
- From a consumption perspective, by which an analysis of minimum calories and daily diets per person, together with that of consumption habits is undertaken.
- From a health perspective: by which the guarantee of a diet in hygienic conditions and the consumption of suitable proportions of food is pursued.
- From a production perspective, by which production techniques, environmental damages, and workers' conditions are analyzed.

The type of analysis will depend on the objective of the institution that makes it. Overall, agribusiness seeks to strengthen their market position and increase their sales. While some multilateral agencies and governments look for system stability and, sometimes, social benefit. However, one of the main challenges of this research is to analyze the agri-food systems in a way that every perspective adds to the characterization of its sustainability.

This section analyzes the four theoretical movements that pursue (directly or indirectly) the sustainability of the agri-food system and that are considered especially significant: Food Security, Sustainable Agriculture, Agroecology and Food Sovereignty. An accurate definition of each of them can help defining the process of analysis undertaken to adopt the perspective upon which this PhD research process will be grounded.

2.1 Food Security

In Spanish, the term food security is used twofold. First, it is used by the agri-food industry to measure the quality of food produced; in other words, it is encompassed within the analysis of industrial production processes as a standard prerequisite for final food consumption. In English there isn't such confusion; the former is called "food safety" and later is "food security".

Second, it is used within the context of international organizations and constitutes a technical concept to evaluate problems related to physical and economic access to food at both national and regional scale. As already expressed, upon this view, food security is reached whenever "every person has at every moment physical and economic access to enough nutritious food in order to

satisfy their food consumption necessities as well as their fundamental preferences and thus be able to carry out a healthy and active life” (World Food Summit, 1996).

This concept, however, has evolved in time and now stands as an issue to address concerns relative to nourishment, social control and public health (Maxwell, 1996). In spite of this evolution, food security remains a non-binding concept, because there is no explicit party obliged to guarantee it, and deals only with collective access to food leaving aside the analysis of individual access (Windfuhr & Jonsén, 2005). According to Patel (2009) food security, as currently defined, could be reached even in hostile situations, like in a dictatorship or prison, since its definition avoids the discussion of the social control of the food system.

During the past century, human society has kept facing relevant problems related to food insecurity; a matter that has forced a change in paradigm to include different social causes (like political instability or marginalization) as fundamental to reach food security (Devereux, 2000). Furthermore, some scholars have recognized the need to include an environmental analysis as an integral part of food security (Patel, 2009), a reason for which la Via Campesina¹¹ has become a supporter of the concept of Food Sovereignty, considering it as a prerequisite to achieve a genuine food security.

2.2 Sustainable Agriculture

The term sustainable agriculture emerges from the necessity to synthesize various concepts and perspectives associated with agricultural practices that differ from those of conventional production by emphasizing a context in which production instability is possible and thus food for current population and future generations is at stake (Neher, 1992). Because this paradigm is essentially understood as a managerial philosophy there is no explicit definition recognized to it, the acceptance or rejection to a particular definition is related to each person’s value system (Abubakar & Attanda, 2013).

The lack of an explicit definition has caused authors to utilize this term with very different connotations across scientific journals, related news, speeches, marketing campaigns, among others; all this has contributed to its ambiguity. Moreover, the concept has been adopted across a

¹¹ La Via Campesina is an international movement that emerges in 1993 from the union of millions of farmers, small producers, indigenous people and migrant workers. Currently it encompasses 164 local and national organizations in 73 different countries.

wide range of scopes that range from intensive use of fertilizers in agricultural industry from production within organic farms.¹²

For the purposes of this project, we have taken into account some definitions that have been focused on an integral view of sustainability. Neher (1992) stated that those definitions of sustainable agriculture contain three main components:

- 1) Environmental quality,
- 2) Ecologic robustness, and
- 3) Productivity of plants and animals and socioeconomic viability.

To exemplify this, the author presents two similar definitions that correspond to the relationship between agriculture and local cultures. The first definition contemplates sustainable agriculture as that by which, in the long run, the quality of environmental and basic resources upon which agriculture relies, are enhanced; one that provides basic food and fiber needs; one that is economically viable and improves the quality of life for farmers and society in general (Abubakar & Attanda, 2013). This definition, adopted by the American Agronomy Society, leaves a wide range for the interpretation of the concept as well as for its use. The second defines it as the ability of an agroecosystem to maintain its production in time (M. A. Altieri, 1987; Neher, 1992). To achieve this it is precise to analyze the agricultural production from a systemic perspective, in which every interacting subsystem that is affected or is prone to affect other subsystems may be contemplated.

2.3 Agroecology

Gliessman (2002) defines agroecology as the “guiding light in the field of sustainable agriculture”, since it seeks to meet the nutritional needs of the population at the same time that conserves and restores natural resources in which agriculture depends on (soil, seeds, water, etc.) and links social equity to food systems sustainability. As outlined by Altieri and Nicholls (2005) and analysis of the interrelatedness of agroecosystems components – ecological, social and economic – is key to building greater self-sufficiency and sustainability into these food systems.

¹² The founder of “organic agriculture”, the American agricultural scientist Frankling Hiram King (1848-1911), visualizes a farm as a sustainable unit, ecologically stable and self-contained.

This concept encompasses the study of agroecosystems, including all environmental and human elements. It focuses on the form, dynamics and functions of their interrelationships and the processes in which they are involved.¹³ Traditional agriculture provided a cultural and ecological basis for its further development as a science (M. A. Altieri & Nicholls, 2005; Gliessman, 2014). Some of its main characteristics are the following (Holt-Giménez & Altieri, 2012):

- It is knowledge-intensive rather than in capital-intensive, as is the current model of agriculture.
- It is based on small ownership and on integral management of agroecosystems rather than in external input systems.
- Agroecology farms are rather small and highly diversified.
- It emphasizes the ability of local communities to generate and amplify innovations through direct research with farmers.

Agroecology currently shows two divergent versions: the reformist and the radical versions. The former attempts to appoint agroecology into the Green Revolution and the latter centers agroecology within a politically transformative peasant movement for Food Sovereignty. Holt-Giménez and Altieri (2012) argue that the livelihoods of smallholders, the elimination of hunger, the restoration of the planet's agrobiodiversity and agroecosystem resilience would all be better served under the alliance between radical agroecologists and Food Sovereignty movement scenario.

2.3.1 Food Sovereignty

This concept arises from the collective effort of certain civil society organizations (CSOs), non-governmental organization (NGOs) and social movements to carry out an international debate with regard to the context of the agri-food system. The debates contemplated a range of topics from production problems to social concerns with regard to the agri-food system. The term appears for the first time in April 1996, as a result of the International Conference of La Via Campesina in Tlaxcala, México (La Via Campesina, 2007).

From its emergence it has been considered a robust alternative that pursues the development of a fair and sustainable agri-food system which guarantees right to food, poverty reduction, social justice and gender equity in the processes of food production.

¹³ Source: <http://www.agroecology.org/>

The proposal has been well received at the international level and in time it has become a reference for debates relative to global food systems, hunger, agriculture and rural poverty (Windfuhr & Jonsén, 2005). Currently, Food Sovereignty is the benchmark for the development of public policy objectives and cooperation projects (Ortega Cerdà & Rivera-Ferre, 2010).

There are different definitions of Food Sovereignty and some of them have changed in time, making it difficult to conceptualize it. The common characteristic in the majority of definitions is the notion that public policies behind food security require a direct democratic participation, the abortion of dumping, a comprehensive agrarian reform and the respect for life, seeds and soil (Patel, 2009).

According to Windfuhr and Jonsén (2005) the most commonly accepted definition is the one proposed by the Food Sovereignty International Planning Committee (IPC) back in 2002, which defines Food Sovereignty as: *“the right of populations to define its own nutrition and agriculture; and protect and regulate the local production and commercialization with the aim to achieve the objectives of sustainable growth, determine the degree of self-sufficiency, restrict dumping, and provide the communities of fishers the priority to manage the use of aquatic resources and their rights. Food Sovereignty does not invalidate commerce, but fosters the formulation of commercialization policies and practices that enhance the rights of population’s nourishment, and sustainable and healthy production.”*

More recently, La Via Campesina defined Food Sovereignty as: *“the right of populations and nations to healthy and culturally appropriate produced food through sustainable methods that are respectful of the natural environment, as well as their right to define their own food and agricultural systems.”*

From the above definitions it is possible to infer that Food Sovereignty is a political tool to assess diverse problems of the environmental, social and economic settings. Its philosophy is both a guide and an inspiration to reduce the production-consumption chain and to empower both consumers and producers of food.

The concept of Food Sovereignty has always referred to both the right to produce and to consume, and acknowledges the right of populations to get access to resources and production means that

permit them to guarantee their self-sufficiency. The concept places the needs of producers above those of markets and enterprises (Declaration of Nyéléni, 2007)¹⁴.

Several authors have discussed the suitability of Food Sovereignty in times of globalization (McMichael, 1996; Windfuhr & Jonsén, 2005). Although some consider the proposal to be contrary to the prevailing market model, Food Sovereignty cannot be considered a proposal against markets; it just raises the necessity of a redistribution of decision-making power among those directly affected by the agri-food policies. It focuses on the right to demand control policy, allocation of resources and decision-making at national and international level by those who are directly affected by such policies; well as trying to promote local democracy and participatory development of national policy (Walelign, 2002).

For Food Sovereignty to stand as an alternative holistic proposal, La Via Campesina developed seven principles (Windfuhr & Jonsén, 2005):

1. **Food, A Basic Human Right:** Everyone must have access to safe, nutritious and culturally appropriate food in sufficient quantity and quality to sustain a healthy life with full human dignity. Each nation should declare that access to food is a constitutional right and guarantee the development of the primary sector to ensure the concrete realization of this fundamental right.
2. **Agrarian Reform:** A genuine agrarian reform is necessary which gives landless and farming people – especially women – ownership and control of the land they work and returns territories to indigenous peoples. The right to land must be free of discrimination on the basis of gender, religion, race, social class or ideology; the land belongs to those who work it.
3. **Protecting Natural Resources:** Food Sovereignty entails the sustainable care and use of natural resources, especially land, water, and seeds and livestock breeds. The people who work the land must have the right to practice sustainable management of natural resources and to conserve biodiversity free of restrictive intellectual property rights. This can only be done from a sound economic basis with security of tenure, healthy soils and reduced use of agro-chemicals.

¹⁴ Source: <http://www.nyeleni.org/spip.php?page=forum&lang=en>

4. **Reorganizing Food Trade:** Food is first and foremost a source of nutrition and only secondarily an item of trade. National agricultural policies must prioritize production for domestic consumption and food self-sufficiency. Food imports must not displace local production nor depress prices.
5. **Ending the Globalization of Hunger:** Food Sovereignty is undermined by multilateral institutions and by speculative capital. The growing control of multinational corporations over agricultural policies has been facilitated by the economic policies of multilateral organizations such as the WTO, World Bank and the IMF. Regulation and taxation of speculative capital and a strictly enforced Code of Conduct for TNCs is therefore needed.
6. **Social Peace:** Everyone has the right to be free from violence. Food must not be used as a weapon. Increasing levels of poverty and marginalization in the countryside, along with the growing oppression of ethnic minorities and indigenous populations, aggravate situations of injustice and hopelessness. The on-going displacement, forced urbanization, repression and increasing incidence of racism of smallholder farmers cannot be tolerated.
7. **Democratic control:** Smallholder farmers must have direct input into formulating agricultural policies at all levels. The United Nations and related organizations will have to undergo a process of democratization to enable this to become a reality. Everyone has the right to honest, accurate information and open and democratic decision-making. These rights form the basis of good governance, accountability and equal participation in economic, political and social life, free from all forms of discrimination. Rural women, in particular, must be granted direct and active decision making on food and rural issues.

2.4 Discussion

Even when targeted in the same direction, each of the above exposed alternatives covers distinct dimensions of the agri-food system sustainability. If focused on the short term it could be argued that hunger eradication and food security is the main objective. However, this objective dismisses the social and environmental contexts and, hence its consecution would not necessarily imply that of the sustainability of the system as a whole.

The concept of sustainable agriculture, in turn, is rather vague and allows contextual interpretations. It could well be that when speaking of agri-food system, sustainable agriculture would stand out as the first concept to measure, yet the lack of a consensual definition makes it difficult to operationalize and measure.

Conversely, Food Sovereignty is not only centered on eradicating hunger, it also seeks to conduct the national food policy to secure sufficient domestic food production through the protection of local producers from global economic forces (La Via Campesina, 2008). It pursues to establish a less vulnerable agri-food system based on agroecological production principles.

2.5 Measuring Food Sovereignty

As a political concept, Food Sovereignty requires analytical tools to position itself as a viable and necessary alternative. Given its complexity, an integrated scientific research agenda that encompasses a large range of disciplines strongly connected to the foundations of agro-ecological and socio-economic modeling is required (Soussana, 2014).

Food Sovereignty has been studied theoretically as an alternative to achieve the right to food, equity and welfare (M. Altieri, 2009; Desmarais, 2003). However, only few studies seek to prove quantitatively whether this proposal has indeed the capacity to achieve the sustainability of the agri-food system. One of them is a study conducted by Ortega-Cerdà and Rivera-Ferre in 2010 in which a set of international indicators that allowed defining the status of Food Sovereignty in each country was proposed.

The authors suggested a set of 128 indicators distributed among the IPC's five pillars that support the Food Sovereignty concept (García, 2003). Each of the pillars tackle a specific aspect of the Food Sovereignty concept according to La Via Campesina's principles (La Via Campesina, 1996). These pillars are:

Pillar One: Access to Resources

"Food Sovereignty attempts to foster and to support individual and community processes on access and control over resources (land, seeds, credit, etc.) in a sustainable manner, respecting usage rights of indigenous communities, particularly emphasizing women's access to resources."

The indicators in this pillar are designed to measure availability, access and control of natural resources in a country or region. They also refer to resource re-distribution and identification in order to fight rural poverty (IFAD, 2010; Windfuhr & Jonsén, 2005).

Pillar Two: Production Models

“Food Sovereignty attempts to increase local and diversified familiar production, recovering, validating and divulging traditional models of agricultural production in an environmentally, socially and culturally sustainable manner. It supports endogenous agricultural development models and the right to produce food.”

These indicators are designed to identify rural population, agricultural and food production activities, land use and resources sustainability, which allow policymakers to favor community, group and individual based decisions (FAO, 2004).

They stand as a conservationist approach, by encouraging agro-ecological practices that would increase productivity on marginal soils and revert the damaging industrial production systems. This could be the right instrument to conserve traditional species, diversify the local biodiversity and hence preserve the environment. Yet, important gaps exist in this group of indicators.

Pillar Three: Transformation and Commercialization

“Food Sovereignty protects the rights of farmers, landless rural workers, fishers, shepherds and indigenous counties to sell their products to feed their local population. Such action implies the creation and support of local markets, and impulse of direct selling or at least with a minimum of intermediaries, depending on the context.”

The indicators of this pillar focus on the right of peasants, rural workers (particularly those without land), fishers, pastoralists and indigenous peoples to sell their products to feed mainly the local population. This involves the creation and support of local sources of distribution, minimizing intermediaries and costs on the food chain.

They could measure the “family type” relationship between local consumers and producers, which is a result of the close and frequent relationship in terms of trade-off and responsibility, favoring powerful trust-based relations between producers and consumers like the individuals of a family. This pillar focuses on self-reliance and promotes a fair trade. It measures the concentration and distribution of products in the local and global markets, and warns against the monopolistic markets.

Pillar Four: Food consumption and Right to Food

“Food Sovereignty protects citizens’ right to consume healthy, nutritive and culturally appropriated food, which comes from local producers and is elaborated with agro-ecological techniques.”

The indicators for this pillar are designed to measure food insecurity in the country or region, focusing primarily in the hunger and the poor; it measures the nutritious status of the people by providing their daily nutritious intake and their minimum requirement.

Likewise, measures the degree of dependence and vulnerability of a country or region by providing information on the three most used groups of food and the concentration of global markets for those groups and on its local production.

Pillar Five: Agrarian Policies

“Food Sovereignty protects farmers’ right to know, participate and influence over the local public policies related with Food Sovereignty.”

In this pillar the indicators attempt to capture the importance given to agriculture through public, private enterprises, as well as government expenditure on agricultural sector. It focuses on the estimated support both for producers and consumers, as well as the general service. It warns from subsidies going directly to trading and storage companies and tries to capture agricultural tariffs, so as to measure the trade obstacles. Likewise, this pillar pays special emphasis on development assistance given or received in order to create awareness of society on the distribution and effective use of their resources.

2.6 Threats

In order to determine whether the food system will be capable of feeding the continuously growing population or not, as well as to identify the system’s vulnerabilities and strengthen them, both actual and potential threats should be identified.

Both the intrinsic complexity of the agri-food system as well as the very different scales at which it develops hinder the understanding of the system as a whole and complicate the capacity of individuals to predict potential consequences (particularly to predict environmental consequences). For example, the IPCC has estimated variability in average temperature zones for different scenarios, which can give us an idea of the possible impact they will have on crops, animals and

people of each of the countries lying within these regions. However, we cannot know with certainty the possible damage that could be generated by unforeseen scenarios and therefore the effects that could be generated indirectly in the field by increasing temperature.

For the purpose of this work, I have identified three main threats that will be further studied:

1. The speculative volatility in food prices derived from their treatment as “commodities” in financial markets.
2. The food shortages generated by the usage of food for alternative “profitable” purposes, such as biofuels or the sweetener industry.
3. The homologation of diets worldwide or “Nutrition Transition”.¹⁵

These three threats have been somehow stressed during the food crisis of the last decades, which has had devastating effects on the poorest population, mostly peasants (Collier, 2008; FAO, 2011). Two of the best examples were observed in 2008 and 2011. In both years famine was the result of food scarcity due to the “strategic management” of food supply carried out by some of the biggest industries, which also generated a brutal increment of basic food prices (Bailey, 2011; Brown, 2011).

One of the official arguments put forth by multinational institutions and governments to support these reckless strategies was that they should match the increase in the consumption in emerging economies for certain kind of food (luxury food¹⁶). Although it could be one important factor given that food consumption patterns are shifting away from basic cereals to fruits, vegetables, meats and oils (Ingram, Ericksen, & Liverman, 2010) and this increment in demand can actually impact food prices, it is far from being the unique reason to explain food scarcity during these crises. A complementary explanation would be the deviation of food products from their target markets due

¹⁵ The term “*Nutrition transition*” refers to the shift in dietary consumption patterns, particularly in developing countries that change from traditional diets strongly based on cereals and fiber to more Western patterned diets, highly rooted on sugars, fat, and animal-source food.

¹⁶ As defined in Otero et al. (2013), luxury foods are value-added foods that make a proportionally lower contribution to caloric intake, as compared to basic foods. This category includes: wine and other alcoholic beverages, fruits, and vegetables.

to investment opportunities. Biofuels, for instance, have become highly profitable over the past years, principally given the subsidies provided by the U.S. and E.U. governments.¹⁷

These and many other threats (e.g. food waste, climate change, soil fertility, land use, etc.) directly affect the sustainability of the agri-food system. Throughout my work I will analyze them in more detail.

3 Research Motivation and Contribution

At a theoretical level, various authors have emphasized the potential for alternative channels of development for the agri-food system that may facilitate the reduction of hunger and rural poverty (Ortega-Cerdà & Rivera-Ferre, 2010; Altieri, 2009) as well as potentiate the sustainable development of rural zones (Desmarais, 2003). Yet, up to date there is no applied research that permits to test the validity of these claims. To the best of this author's knowledge, the work undertaken in my Master's Final Thesis (MFT), which is grounded on the set of relevant indicators previously developed by Ortega-Cerdà and Rivera-Ferre (2010), stands as one of the initial attempts to formulate a concrete measure that allow to assess and quantify Food Sovereignty across countries.

The growing acceptance of the concept of Food Sovereignty as a robust and viable alternative to eradicate undernourishment, promote rural development and mitigate the environmental crisis (Nicastro, 2012), evidences the relevance of this research project, whose final outcome would be a key tool (or system of tools) that permits to efficiently assess the success of the alternative production models above described.

The research here presented, hence, is strongly motivated upon the potential adoption of Food Sovereignty and seeks to contribute to the quantitative and qualitative analysis of the agri-food system, with the aim to put forth tools that allow to measure and interpret the system functioning and its degree of sustainability. I have already made an initial approximation through the study presented in the above-mentioned MFT, where an international index of Food Sovereignty is proposed (IIFS) as a tool to measure Food Sovereignty across countries or regions. I focused the analysis of such index in Latin American countries and assessed whether its constituent countries have adopted Food Sovereignty principles in their legislations.

¹⁷ <http://cadtm.org/Getting-to-the-root-causes-of-the#nb13-7>

A thorough analysis of the pros and cons of the methodology used for this MFT, restated a common result for this kind of methodologies: the fact that while concentrating indicators into a single index facilitates decision making processes, but it also dismisses valuable information which prevents detailed analysis. Consequently, we determined to adapt the scope of the index, undertaking a more systemic methodology.

Accordingly, I will center my doctoral research in the agri-food system from a systemic perspective with the purpose to contribute to this field of knowledge by advancing a set of tools that allow other colleagues to pursue empirically and in depth comparative analysis with regard to the sustainability of the agri-food system worldwide. More specifically this project will contribute to this field of knowledge by:

- Advancing a set of indicators able to adequately describe the status of Food Sovereignty at country level and to include the maximum amount of information regarding agri-food systems description.
- Applying statistical methodologies based on maximum information and nonparametric exploration that allow unveiling the nature of the interactions among the previously mentioned set of indicators, and hence that allows grouping them in meaningful tranches.
- Modeling the evolution and correlation of significant indicators in order to develop appropriate analytical expressions able to explain the global structure of the agri-food system.
- Providing a standardized set of indicators as a reference for cross-countries' agri-food system comparison.

3.1 Objectives

Main objective:

The main objective of this work is to establish key parameters that allow characterizing the degree of sustainability of the global agri-food system, through the study and analysis of its agents, interactions, main strengths and vulnerabilities.

Secondary objectives

In order to reach the main objective, the following secondary objectives must be reached:

1. A conceptual analysis of the main alternatives that foster the sustainability of the agri-food system.
2. A methodological analysis, that incorporates and reviews the methodology previously put forth in my MFT, as well as other related works.

The accomplishment of these secondary objectives contemplates, the following steps:

- a. To conduct a cross-correlation analysis for the set of variables proposed on my MFT, with the aim to disentangle their existing interactions and assess their contribution to the dynamics of the agri-food system.
 - b. To evaluate and calibrate their potential for clustering within one or various index categories (composed indicators) that permit cross-country comparisons.
 - c. To design a model to monitor the agri-food system as a complex socio-economic system (SES).
3. To propose a benchmark for the study of the Food Sovereignty evolution at country level, based on the resulting variables derived from objective 2a.
 4. A robustness analysis of the results through the comparison of similar methodologies and their results.
 5. To unveil the main threats that may impact (either directly or indirectly) the behavior of the system. For instance:
 - a. The use of food as a source of energy supply
 - b. Price volatility of commodities
 - c. Changes in food preferences, due to cultural influence or variations in distribution channels.
 - d. Climate change and its potential effects.
 6. Finally, to come up with a qualitative and quantitative measure for the sustainability of the agri-food system.

3.2 Viability and Limitations

There exist a series of constraints for the consecution of the current project. Some of such limitations were previously identified during the stage of production of the MFT. During the subsequent stages I expect to amend their consequences. Other limitations have been identified afterwards. Among these, the following stand out:

- The project requires dealing with indicators of different nature (social, environmental and economic). This poses two main difficulties: (1) it is assumed that the greater the number of indicators that constitute an index, the lower its individual impact in the final index, hence the index might be not very sensible to sharp movements in the indicators that compose it; and (2) Despite the enormous amount of resulting indicators (96 allocated in 5 pillars) there are certain aspects of Food Sovereignty that cannot be tackled because of lack of information (in other words, for certain aspects the indicators do not clearly reflect the essence of Food Sovereignty as a whole, i.e. local markets).
- Private interests in the agri-food system difficult access to information across countries. For example, with regard to information on seeds, we have found out that most databases are private. In a similar fashion, certain countries that do not belong to a collective of international organisms offer scarcer information in comparison to others, which do belong to such organisms, such as the case of OECD countries, for instance.
- Political instability makes it difficult to gather consistent time series. For our study, we have incorporated those countries that form part of the UN since 1993. However, the collection of information beyond this date is a difficult task.
- The SES framework contemplates certain inherent limitations: (i) traditionally this framework has been used for the management of natural resources under ecological principles, as such it is assumed that social and ecological dynamics are essentially similar; (ii) because it is a recent framework, its design does not allow to introduce normative questions that set aside the role of power, culture or alternative views of socio-ecological systems (Vallejo-Rojas et al., 2013).

Quantitative analysis regarding the sustainability of the agri-food system entails a number of limitations that may discourage these types of projects. But as Holling (2001) proposes, *“we must work in defining what is known, what is unknown as what is uncertain, because we always stick to the better judgment and not to the best certainty”*.

3.3 Methodology

The methodology used in this work pretends to ensure the proper study and measurement of the entire agri-food systems structure and its functions. This methodology is grounded on three main streams of action: a conceptual one, aimed at analyzing and evaluating alternative strategies and indicators), an empirical one, aimed at running correlations among indicators and an interventionist

one, aimed at identifying system vulnerabilities and establishing proposals for future policy assessments.

Accordingly, I have undertaken this research into a three-stage process: The first one consists in selecting the relevant variables and components that may constitute the framework. The second one is the correlation analysis, which shall be centered in knowing and determining the interactions among indicators, and the design of a simple model that captures interactions among significant variables. Finally, the third stage consists in determining which presentation tools facilitate the comprehension of the final results (i.e., the characterization of the sustainability of the agri-food system). Each one of the three steps is detail in the following sub-sections.

3.3.1 Selection of Variables

The adoption of the proper indicators has become a central debate of the Sustainable Development. A large number of national and international organizations and academic institutions have conducted significant related research in the field (Gasparatos, El-Haram, & Horner, 2008). Consequently, they can provide benchmark guidance for this task.

Agricultural and food studies, specifically those aiming to assess the food systems under policies of Food Sovereignty, have centered their research mainly in the development of Food Sovereignty indicators (Institut d'Economia Ecològica i Ecologia Política & Entrepobles, 2010). Ortega-Cerdà and Rivera-Ferre (2010) identified more than 350 indicators as potentially relevant for Food Sovereignty; analyzed them and came out with 128 indicators that fulfilled the following criteria:

- Adaptation to Food Sovereignty discourse and contextual relevance.
- Preference for indicators that are already collected and published by international organizations.
- Preference for indicators collected in the maximum number of countries.
- Preference for the indicators whit historical data as broad as possible.

Given the scale (country level) and the system approach analysis that defines this research, three additional criteria become necessary:

- Indicators must allow comparisons at country-level.
- Must provide essential and unique information in an aggregated level, and
- Data must be publicly available for each indicator.

Those data represents the best available choices at this time. Most of the data sources used were of recognized standing and provided an international scope in agriculture and food in all their dimensions (social, ecological, economical). The majority of them come from online public available databases; yet a few of them are not publicly available (e.g., IMF database available only for a few days with the free trial option).

The main data sources were:

- Institutions, agencies and programs related to the United Nations Organization (UN): Food and Agriculture Organization (FAOSTAT, FAO statistical year book, FAO Statistical Division, FAO-Food Security, TERRASTAT, FISHSTAT and AQUASTAT), United Nation Development Program (UNDP), United Nations Environment Programme (UNEP and GEODATA), Millennium Indicators.
- International Financial Institutions: World Bank's (WB) World Development Indicators (WDI) and International Monetary Fund (IMF).
- Other international organizations: Organization for Economic Cooperation and Development (OECD), World Trade Organization (WTO), See Around Us, World Resources Institute, Action Group on Erosion, Technology and Concentration (ETC) and Agricultural Science and Technology Institute (ASTI).

To this date, 86 indicators (see Annex 1) have been incorporated into the framework that will be used to run the correlation analysis. Almost all of these indicators have been standardized with another indicator, allowing comparability across countries (e.g., agricultural tractors and capital stock in agriculture are divided by agricultural area and agricultural income per capita respectively).¹⁸

The indicators are distributed across the five pillars outlined before; this allows detailed analysis for each of the pillar's specific topic. Pillar-based analysis offers two additional advantages: it may allow us to make policy recommendations regarding specific issues to certain countries or regions, and it may also enable to decompose country based trends and differentiate them from general trends.

¹⁸ In each case we ensured that the denominator also met the selection criteria.

3.3.2 Correlation Analysis

Systems are intrinsically complex and cannot be completely understood by analyzing each part on an individual basis, because the actions among its agents or parts define the system itself. A cross-correlation analysis would clarify some of the existing interactions among the different agents of the agri-food systems.

Increasingly, environmental evaluation methods are moving towards integrated assessments by:

- i) Incorporating several environmental dimensions (e.g., cultural services, as the gains people attain from the natural environment for recreational, cultural and spiritual purposes).
- ii) Connecting local and global issues (e.g., indirect changes in land usage arising from the expansion of biofuel on arable lands have been identified as likely causes of tropical deforestation leading to large indirect emissions of carbon dioxide (Searchinger et al., 2008)); and
- iii) Assessing long-term effects, as well as non-linearities and thresholds. More attention is now being paid to some of the long-term consequences of current decisions and policies (Paillard, Treyer, & Doring, 2011).

A major challenge in monitoring agri-food system sustainability is to develop techniques that identify its interactions at different scales (Neher, 1992).

The objective of this analysis is twofold: on one side it seeks to discard unnecessary variables either because they are redundant or because they do not provide enough data to be properly compared; and on the other side it seeks to establish the nature of the interactions taking place among the remaining variables.

Two different perspectives are considered for this analysis: linear and non-linear correlation. For the first one I will use the conventional Pearson and/or Spearman coefficients, that assesses pairwise linear correlations between different sets of variables. For the second analysis, I will use a methodology introduced by Reshef et al. (2011), known as “Maximal Information Coefficient” (MIC), this tool enables to describe the correlation between paired variables regardless of the linearity of their relationship.

The intuition behind MIC is that if a relationship between two variables exists, then a grid can be drawn representing the relationship. The MIC satisfies two heuristic properties: generality and equitability. The first one is satisfied when with “sufficient sample size, the statistic should capture a

wide range of interesting association, not limited to specific function types, or even to all functional relationships". The second property holds that "the statistic should give similar scores to equally noisy relationship of different types".

Formally, MIC is defined as follows:

Definition. For a grid G , let I_G denote the mutual information of the probability distribution induced in the boxes of G , where the probability of the box is proportional for the number of data points falling inside de box. The (x,y) -th entry $m_{x,y}$ of the characteristic matrix equals $\max\{I_G\}/\log \min\{x,y\}$, where the maximum is taken over all x -by- y grids G . MIC is the maximum of $m_{x,y}$ over ordered pairs (x,y) such that $xy < B$, where B is a function of sample size (usually $B = n^{0.6}$).

In my research I will use MIC tool to identify non-linear relationship among the indicators in the underlying framework to understand better the complexity of the agri-food system and to avoid duplicity and misinterpretations.

Finally, an equation-based model will be developed, parameterized and calibrated in order to explicitly quantify, when possible, the evolution and relations among significant variables. This final step should give robust and appropriate analytical expressions able to explain the global structure of the agri-food system.

3.3.3 Main effect

One of the main objectives of my MFT was to develop a unique measure that allows ranking countries given its Food Sovereignty level. That is how the International Index of Food Sovereignty (IIFS) came out, as a linear aggregation of 96 Food Sovereignty indicators. To build the IIFS we choose to equal weighting each indicator for the sake of neutrality, since we recognize that there may be legitimate differences of opinion regarding the relative importance of each pillar as well as each indicator from country to country. For example, the access to resources might be more important for the developing countries while agrarian policy would be more important for the developed ones.

There is no consensus among experts with regard to the best methodological strategy for combining variables to construct the composite index; particularly in relation to the weighting and aggregation processes, because these are considered particularly sensitive, subjective and

normative¹⁹ (Paruolo, Saisana, & Saltelli, 2013; Saltelli, 2006; Wolff, Chong, & Auffhammer, 2008). Notwithstanding, the general idea of aggregating indicators into a single index has been proposed as a way to make progress (e.g., in soils processes (Garrigues et al., 2012)).

The linear aggregation of indicators implies some methodological issues, particularly the compensatory characteristic of this type of aggregations (i.e., weakness in some dimensions is compensated by strengths in other dimensions). Thus the real importance of each variable is not necessarily the initial weight or the expected importance of the variable. This issue is particularly important in the case of pillar base composite indicators, as is the case for the IIFS.

Paruolo, Saisana and Saltelli (2013) address this issue by calculating variable's main effect in composite indicators. The main effect is first-order sensitivity measure that represents *the expected relative variance reduction obtained in the index if a given input variable is fixed*. In their work they show that there are discrepancies between relative nominal weights, those intended to give the variables by assigning a weight, and the actual importance of each variable (the main effect).

In the case of pillar-base composite indicators the authors tested three indexes:

- The so-called Human Development Index (HDI) with 2010 methodology.
- The Ibrahim Index of African Governance (IIAG) developed by Harvard Kennedy School in which 48 African countries are ranked according to five pillars: safety and security; rule of law, transparency and corruption; participation and human rights; sustainable economic opportunity, and human development.²⁰
- The Sustainable Society Index (SSI) developed by the Sustainable Society Foundation²¹ formed by five pillars with different weights on each of them: personal development (weight 1/7); healthy environment (weight 1/7); well-balanced society (1/7); sustainable use of resources (2/7), and sustainable world (2/7).

¹⁹ As in Paruolo et al. (2013) *normative is understood to be 'related to and dependent on a system of norms and values'*.

²⁰ For more detail see <http://www.moibrahimfoundation.org/iag/>

²¹ For more detail see <http://www.sfindex.com/ssi/>

They found discrepancies in the three cases. In the case of the HDI discrepancies were very little; for the IAG significant discrepancies were found in the fifth pillar; and in the case of the SSI “notable differences” were found for the five pillars.²²

This methodology can complement robustness analysis applied to composite indicators. I will apply it to determine whether the relative effect of the pillars equals the relative importance of the indicators in the IIFS. This exercise will show if each pillar is equally represented on the final index and on the framework proposed in the working paper, and thus the whole picture of Food Sovereignty is well characterized.

4 Work in Progress

To this date, there has been progress both in the structure of the project and in the fulfillment of four of the secondary objectives above detailed. Next, I present the work in progress of each of these objectives:

1. **Conceptual Analysis:** I have attempted to deepen our analysis of the alternative channels for the agri-food system sustainability with the aim of establishing a standardized framework that works as a benchmark for both my subsequent doctoral research as well as for the conduction of further related studies.

The conceptual analysis has been part of the literature review since the beginning of my research and is being updated ever since. Within this process I have first defined the agri-food system and the four major alternatives proposed by different social organizations worldwide: (i) food security, (ii) sustainable agriculture, (iii) agroecology and (iv) Food Sovereignty.

2. **Methodological Analysis:** I have compared the methodology used at the beginning of my research (during my master degree stage) with other methodologies developed by researchers of other Spanish and Latin-American universities and academic institutions. Along this stage, I have evaluated the suitability of composed indicators for each of the five pillars proposed by García (2003). However, in a second stage it was noticed that these approach was not optimal to efficiently reflect a complex system such as that of the agri-

²² In 2010 SSI improved its methodology due to this assessment.

food. Consequently, I adopted the alternative approach to analyze the system from a SES perspective, which allows a cross-scale analysis.

3. Derived from the explicit recognition of a reference framework, during the 2012 FAO regional conference, I developed in my MFT a set of 96 indicators allocated along the five pillars labeled: access to resources, production models, transformation and commercialization, food security and food consumption, and agricultural policies.

During the first twelve months of my doctoral studies I have kept working on updating and refining such database, as well as on identifying whether each of these indicators is indeed suitable for the pillar of reference. Parallel to this, I am undertaking a correlation analysis among the proposed indicators to unveil the nature of their interactions and evaluate their contribution to the study of the dynamics of the agri-food system.

The resulting indicators from this process will constitute an updated framework upon which further research projects can be grounded. To date 86 indicators form the underlying framework (Annex 1), which is expected to be published in the first half of 2015. This paper aims to be a reference article to scholars working on assessing the sustainability of the agri-food system.

In addition to the difficulty of designing of the framework, the construction of the database with all the information has been a complicated task. As of December 2014, more than 500 thousand data has been collected and it is expected to continue growing the following weeks. Particularly since a new transversal pillar has been added to the database regarding gender in agriculture.²³

4. Finally, I have advanced in the literature review to identify the main threats of the agri-food system. As mentioned above I have centered my attention in the analysis of three potential threats:
 - a. The speculative volatility of food commodities and its role on the recent food crises.

²³ This late addition is on early stages, so any additional information regarding structure and contents can't be mentioned on the present work.

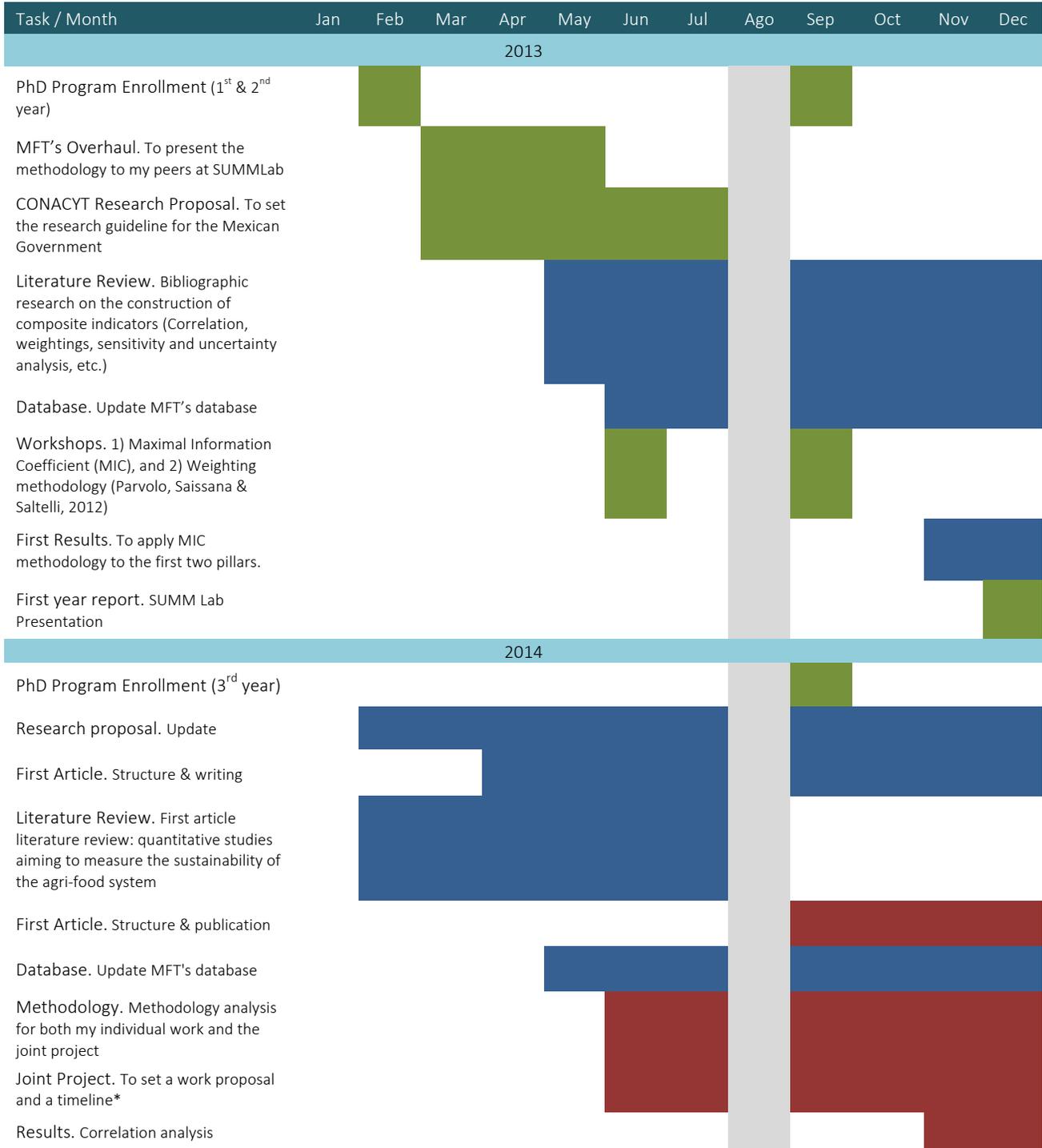
- b.** The debate behind the production of agrofuels/biofuels as alternatives to the use of fossil and the impact generated along the problem of undernourishment in certain regions.
- c.** The impact of the agri-food industry in preference changes due to either modifications in the distribution channels or social influence.

Given its nature, I expect to fulfill the objectives of robustness analysis and characterization of the agri-food system sustainability after the complete fulfillment of the previous secondary objectives.

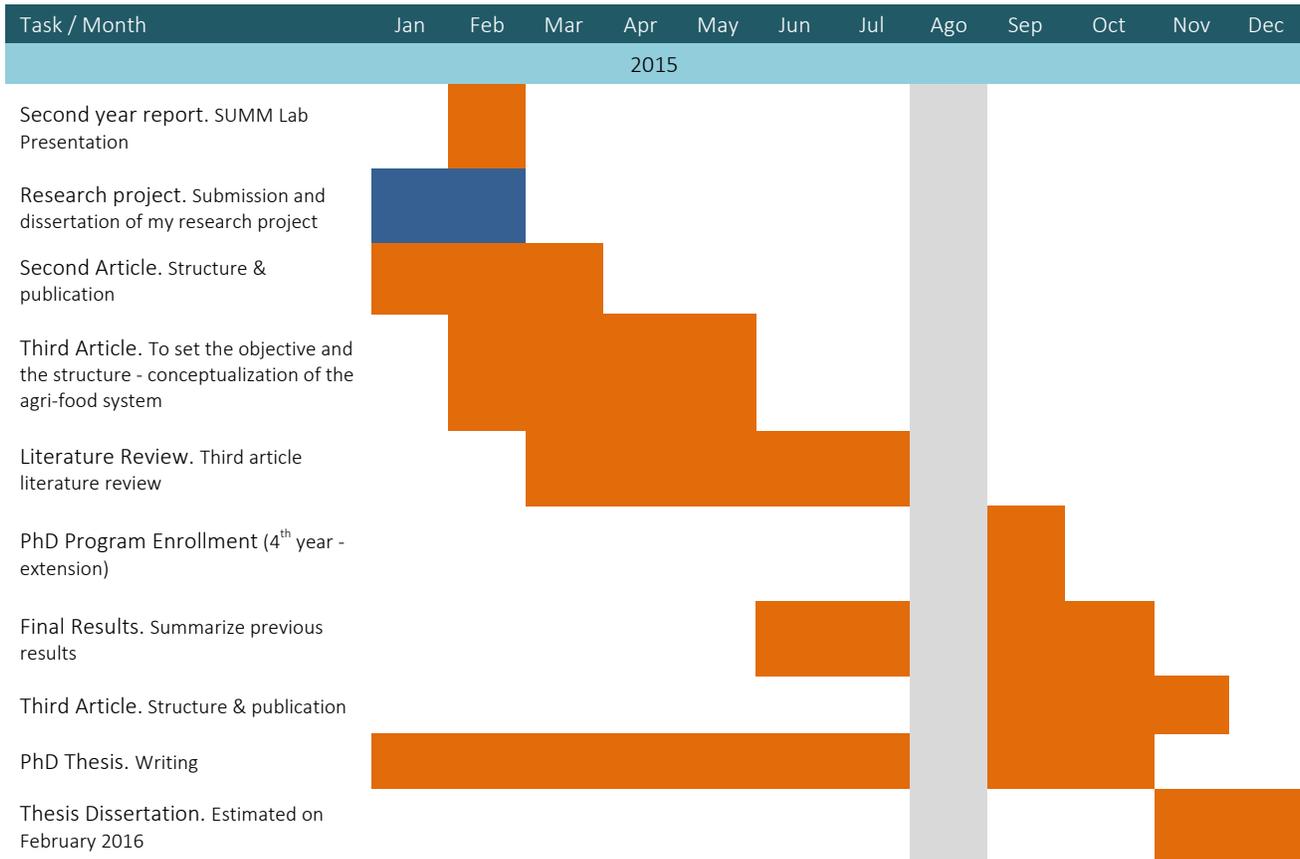
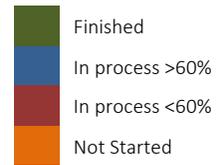
This work has produced a collateral research project in collaboration with Alexandra Ivón Palomino and Elisa Oteros-Rozas from universities in Bogota and Madrid respectively; by which we aim to develop and quantify the concept of food debt. This collaboration is still at the stage where we are gathering the database.

5 Timetable

Last Review: December 2014



Last Review: December 2014



* The timeline of the joint project is not yet defined

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7 Other Quality Indicators

7.1 Funding

In August 2013 the National Council for Science and Technology (CONACYT for its acronym in Spanish), a Mexican Government institution, gave me the required funds to continue my graduate studies in sustainability at the UPC. This funding will last until January 2016.

One of the requisites was presenting a research proposal for evaluation by the expert committee of the institution. The research proposal I submitted contained the first outline of what I present in this work.

7.2 SUMM Lab Sessions

SUMM Lab team organizes periodical sessions in which one member presents research topics, either of her own work or a related article or useful tool, to the other members for its discussion.

To date I have presented five times:

- In the fall of 2012 I presented the methodology used on my MFT and some results to give my colleagues an idea of what I was interested in working. I was interesting in hearing other opinions that could enrich my work.
- In the first half of 2013 I presented the Maximal Information Coefficient (MIC) methodology to my colleagues in order to both: assess the applicability of this methodology to my work and knowledge-sharing.
- Later the same year I explained in the session the weighting methodology introduced by Paruolo et al. (2013) in their article Science or Vodoo?, with the same objectives as before: to assess suitability and knowledge-sharing.
- At last, in 2014 I presented twice an advance of my work thus far.

Additionally, I have tried to actively participated in sessions where my colleagues presents, with constructive reviews and support.

Annex 1 – Indicators Framework

Last updated: December 2014.

	Indicator	Source
Pillar 1 - Access to Resources		
Basic Infrastructure and Services		
111	Rural Access Index (Percentage of rural population with access to roads in all seasons)	World Bank
112	Rural household access to electricity (percentage)	World Bank
113	Total net enrollment ratio in primary education, both sexes (percentage)	MDG
114	Proportion of rural population using an improved sanitation facility (percentage)	UN Data
115	Proportion of rural population using an improved drinking water source (percentage)	UN Data
Land, Forest and Marine Resources		
121	Agricultural area (hectares per capita)	FAOSTAT
122	Cultivated area (hectares per capita - agricultural population)	FAOSTAT
123	GINI Land Index	FAO Statistical Yearbook 2010
Animals		
131	Domestic mammals per rural inhabitant (except pack animals)	FAOSTAT
132	Poultry animals per rural inhabitant	FAOSTAT
133	Pack animals per square km of agricultural area	FAOSTAT
Water		
141	Total internal renewable per capita (cubic metres per capita per year)	AQUASTAT
Industrial Machinery		
151	Agricultural tractors per 1000 hectares of agricultural area	FAOSTAT
152	Combine harvesters - threshers per 1000 hectares of agricultural area	FAOSTAT
153	Milking machines per head of cattle	FAOSTAT
Capital Stock		
161	Capital Stock (constant 2005 USD) per agricultural population	WDI
Pillar 2 - Productive Models		
Population & Employment		
211	Rural population (% of total population)	FAOSTAT
212	Agricultural population (% of total population)	FAOSTAT
213	Total economically active population in agriculture (% of total employment)	FAOSTAT
214	Female economically active population in agriculture (% of total female employment)	FAOSTAT
Land Use		
221	Permanent crops (% of agricultural area)	FAOSTAT
222	Meadows and permanent pasture (% of agricultural area)	FAOSTAT
223	Forest area (% of agricultural area)	FAOSTAT
224	Flooded area by irrigation and natural form (% of agricultural area)	AQUASTAT

	Indicator	Source
225	Temporary crops (% of agricultural area)	FAOSTAT
226	Temporary meadows and pastures (% of agricultural area)	FAOSTAT
Production		
231	Production of cereals per person (kg / person)	FAOSTAT
232	Production of meat per person (kg / person)	FAOSTAT
233	Production of fruit per person - excluding melons (kg / person)	FAOSTAT
234	Fishery production per person (kg / person)	FishStatJ
235	Forest harvest rate (extraction as a % of volume forest)	Geodata
Agricultural Inputs		
241	Intensity of the total fertilizer use (tons / hectare of cultivated area)	FAOSTAT
242	Intensity of total pesticides use (tons / hectare of cultivated area)	FAOSTAT
243	Substance use for seed treatment - fungicides and insecticides (tons / hectare of cultivated superficie)	FAOSTAT
244	Total actual renewable water resources withdrawn by agriculture (%)	AQUASTAT
Polluting Emissions & Natural Resource Degradation Due to Production		
251	Water pollution, food industry (% of total BOD emissions)	WDI
252	Land degradation due to the agricultural activities (% of total area)	TERRASTAT
253	Percentage of area equipped for full control irrigation salinized (%)	AQUASTAT
Economic Characteristics		
261	Poverty headcount ratio at rural poverty line (% of rural population)	WDI
262	Value added in agriculture (% of GDP)	WDI
Agroecology Sustainable Production		
271	Conservation agriculture area (% of cultivated area)	AQUASTAT
272	Organic agricultural area (% of total agricultural area)	IFOAM & FIBL
Pillar 3 - Transformation and Marketing		
International Trade		
311	Agricultural raw materials exports (% of merchandise exports in dollars)	WDI
312	Agricultural raw materials imports (% of merchandise imports in dollars)	WDI
313	Food exports (% of merchandise exports in dollars)	WDI
314	Food imports (% of merchandise imports in dollars)	WDI
315	Fishery imports (% of imports, in dollars)	FAOSTAT & FishStatJ
316	Fishery exports (% of exports, in dollars)	FAOSTAT & FishStatJ
317	Imports of forest products (% of imports, in dollar terms)	FAOSTAT & FORESTAT
318	Exports of forest products (% of exports, in dollar terms)	FAOSTAT & FORESTAT
Purchasing Price Of Farmers		
321	Price paid to farmers in terms of dollars per ton of the five products with more production in the country (% of income per agricultural inhabitant)	FAO Statistics Division

	Indicator	Source
Industrial Production And Manipulation		
331	Food, beverages and tobacco (% of value added in manufacturing)	WDI
332	Percentage of top 3 food groups in terms of production quantity	FAOSTAT
Positioning In The Global Production Of Food Resources		
341	Cereal production (% of world production)	FAOSTAT
342	Meat production (% of world production)	FAOSTAT
343	Fishery production (% of world production)	FISHSTAT
Pillar 4 - Food Security and Food Consumption		
Food Scarcity		
411	Prevalence of undernourishment in total population (%)	JMP
412	Children under 5 moderately or severely underweight (%)	MDG
413	Food deficit of undernourished population (kcal/person/day)	WDI
414	GINI coefficient for food consumption (dietary energy consumption)	FAOSTAT
Food & Nutrients Consumption		
423	Dietary energy consumption (kcal/person/day)	FAOSTAT
424	Dietary protein consumption (g/person/day)	FAOSTAT
425	Dietary fat consumption (g/person/day)	FAOSTAT
Buying Effort		
431	Share of food consumption expenditure in total household consumption expenditure (%)	FAOSTAT
External Food Dependency		
441	Cereal import (% of cereal production volume)	FAOSTAT
442	Cereal export (% of cereal production volume)	FAOSTAT
443	Meat import (% of meat production volume)	FAOSTAT
444	Meat export (% of meat production volume)	FAOSTAT
445	Fishery import (% of fishery production volume)	FAOSTAT
446	Fishery export (% of fishery production volume)	FAOSTAT
447	Share of food aid in total consumption (%)	FAOSTAT
448	Seed import as a ratio of seed export (volume)	ISF
Pillar 5 - Agrarian Policies		
Governmental Expenditure		
511	Percentage of agricultural in total spending (%)	IFPRI
512	Noncash general government expenditure on agriculture, forestry, fishing and hunting (% of agricultural value added)	FAOSTAT
513	Public agricultural R&D expenditures (% of agricultural GDP)	ASTI
Distribution Of Governmental Expenditure on Agricultural Support		
521	Total support estimate (TSE) (€ millions)	OECD
522	Producer support estimate (PSE) (% of value of production)	OECD
523	Producer support estimate (PSE) (% of TSE)	OECD
524	Consumer support estimate (CSE) (% of TSE)	OECD
525	Estimation of general services support agriculture (GSSE) (% of TSE)	OECD

Indicator		Source
Official Development Assistance Dedicated to Agriculture		
531	ODA received or contributed to agriculture, forestry and fishing (\$ million, current prices)	OECD
532	ODA received or contributed to agrarian reform (\$ million, current prices)	OECD
533	ODA received or contributed to agriculture, forestry and fishing in the form of donation (\$ million, current prices)	OECD
Tariffs Related to International Trade of Agricultural Products		
541	Final bound simple average for agricultural products	WTO
542	MFN (Most Favored Nation) tariff, simple average for import duties for agricultural products	WTO
543	Trade weighted average tariffs for agricultural products	WTO