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INTEGRATED ASSESSMENT AND SUSTAINABILITY FRAMEWORKS. DIAGNOSIS, DESIGN AND APPLICATION OF AN ADAPTIVE TOOL

THESIS PRESENTED TO OBTAIN THE PH.D. TITLE FROM THE POLYTECHNIC UNIVERSITY OF CATALONIA

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When a farmer plows for planting, does he plow continually? Does he keep on breaking up and working the soil? When he has leveled the surface, does he not sow caraway and scatter cumin? Does he not plant wheat in its place, barley in its plot, and spelt in its field? His God instructs him and teaches him the right way.

Isaiah 28:24-26.

¿Acaso el que ara para sembrar, ara todo el tiempo, rompiendo y surcando su terreno? Después de haber emparejado la superficie, ¿no esparce el eneldo, arroja el comino y pone el trigo en hileras, y la cebada en su lugar, y el centeno en el borde? Porque su Dios lo instruye, y le enseña lo que es conveniente

Isaías 28:24-25.

Tots sabeu que el camperol, quan vol sembrar, no llaura tot el dia, removent la terra i fent-hi solcs. Quan ha replanat la terra, escampa la pebreta i el comí, sembra en un bon indret el blat i l'ordi, i, en els marges, l'espelta. El seu Déu, que l'instrueix, li ensenya com cal treballar.

Isaïes 28:24-26

ABSTRACT

The present Ph.D. thesis aims to close a gap found in literature regarding the availability of a sustainability integrated assessment method to be carried at local level where generally, data and resources are restricted and variable over time. After starting with a review on the most relevant sustainability frameworks and assessment methods, I was faced with the question of how these elements could be implemented on field. I found answers through a case study: the project “Promotion and development of organic agriculture for grain producers in Jalisco, Mexico”. Making two field visits to the study area was crucial for me to verify the suitability of the designed adaptive integrated assessment tool for evaluating sustainability of local agroecosystems with the participation of local farmers. Finally, I expanded the tool to incorporate a dynamic assessment of the analyzed elements with a systems-based approach. The research process I followed consisted on the preparation, submission and publication of papers corresponding to each one of the chapters here presented. The most significant result of my research is the in-field validation of an adaptive and integrated sustainability assessment tool that applied to contrast the management of agroecosystems proved to be useful for: consolidating the sustainability approach, driving decision-making processes and bringing tangible results at local level. I encountered some obstacles as well: the transversal scope of the research that translated in greater complexity; the struggle between the long-termed sustainability goals and the requirement for immediate results; data gaps and the colliding vision of farmers and public institutions over the agricultural issues observed in the study area. To overcome these obstacles, the research in a broad sense, points to the recognition of sustainable agriculture as a necessity for people and in a practical one, provides a method that is fully driven at local level with a flexible indicator set and a multidimensional participatory approach. This research is meant to help sustainability in moving beyond theoretical debates and towards a practical influence for decision-making at local level.

Keywords: sustainability, agroecosystems, sustainability frameworks, integrated assessment, local context.

Resumen

La presente tesis doctoral tiene como objetivo reducir una brecha encontrada en la literatura en torno a la conducción de un análisis integrado de la sostenibilidad a nivel local, donde generalmente la disponibilidad de datos y recursos es limitada y variable. Comenzando con la revisión de los más relevantes marcos teóricos y los métodos de evaluación de la sostenibilidad, surgió la cuestión de cómo estos elementos podían ser implementados a nivel práctico. Las respuestas fueron encontradas a través del caso de estudio: el proyecto "Promoción y desarrollo de la agricultura orgánica para productores de granos del estado de Jalisco, México". Dos visitas de campo al área de estudio fueron cruciales para verificar si la herramienta diseñada era adecuada para el análisis integrado de la sostenibilidad en agroecosistemas locales con la participación de los productores. Finalmente, la herramienta fue ampliada para incorporar el análisis dinámico de los elementos evaluados mediante un enfoque sistémico. El proceso de investigación se llevó a cabo a través de la preparación, postulación y publicación de artículos científicos correspondientes a cada capítulo. El resultado más significativo, fue la validación en el terreno de una herramienta adaptativa e integrada para la evaluación de la sostenibilidad que, aplicada para contrastar el manejo de los agroecosistemas, demostró ser útil para: consolidar el enfoque de la sostenibilidad, dirigir los procesos de toma de decisiones y aportar resultados tangibles a nivel local. Algunos obstáculos también fueron encontrados: la transversalidad del tema de investigación que se tradujo en una mayor complejidad; la lucha entre las metas a largo plazo de la sostenibilidad y la demanda de resultados inmediatos; los datos discontinuos y las visiones encontradas de los productores y las instituciones públicas en torno a la problemática observada. Para superar dichos obstáculos, en sentido amplio, esta investigación señala la importancia de reconocer la agricultura sostenible como una necesidad para los pueblos. En un sentido más práctico, proporciona un método que se implementa a nivel local de principio a fin a través de un set flexible de indicadores y un enfoque multidimensional y participativo. Esta investigación, pretende ayudar a que la sostenibilidad supere los debates teóricos para convertirse en una influencia práctica en la toma de decisiones a nivel local.

Palabras clave: sostenibilidad, agroecosistemas, marcos teóricos, análisis integrado, contexto local.

RESUM

Aquesta tesi doctoral té com a objectiu reduir una bretxa trobada a la literatura especialitzada quant a la conducció d'una anàlisi integrat de la sostenibilitat en l'àmbit local, on generalment la disponibilitat de dades i altres recursos és limitada i variable. Començant amb una revisió dels més rellevants marcs teòrics i els mètodes d'avaluació de la sostenibilitat, va sorgir la qüestió de com aquests elements podien ser implementats pràcticament. Les respostes s'han trobat a través del cas d'estudi: el projecte "Promoció i desenvolupament de l'agricultura orgànica per productors de gra de l'estat de Jalisco, Mèxic". Duges visites de camp a l'àrea d'estudi, van ser crucials per verificar si l'eina dissenyada va estar l'adequada per l'anàlisi integrat de la sostenibilitat en els agroecosistemes locals amb la participació dels productors. Finalment, l'eina va ser ampliada per incorporar l'anàlisi dinàmic dels elements avaluats per mitjà de l'enfocament sistèmic. El procés de la recerca es va dur a terme a través de la preparació, presentació i publicació d'articles científics corresponents a cada capítol. El resultat més significatiu, ha estat la validació al terreny d'una eina adaptativa i integrada per a l'avaluació de la sostenibilitat que, aplicada per contrastar el maneig dels agroecosistemes, va demostrar la seva utilitat per a: consolidar l'enfocament de la sostenibilitat, dirigir els processos de presa de decisions i aportar resultats tangibles a escala local. Alguns obstacles també s'han trobat: la transversalitat del tema de la recerca, que s'ha traduït en una major complexitat; la lluita entre les metes a llarg termini de la sostenibilitat i la demanda de resultats immediats; la discontinuïtat de les dades i les visions contraposades dels productors i les institucions públiques al voltant de la problemàtica observada. Per poder superar aquests obstacles, en un sentit ample aquesta recerca senyala l'importància de reconèixer l'agricultura orgànica com a una necessitat pels pobles. En un sentit més pràctic, proporciona un mètode que s'implementa a nivell local de principi a fi a través d'un set flexible d'indicadores i un enfocament multidimensional i participatiu. Aquesta recerca pretén ajudar que la sostenibilitat superi els debats teòrics per esdevenir una influència practica a la presa de decisions en l'àmbit local.

Paraules clau: sostenibilitat, agroecosistemes, marcs teòrics, anàlisi integrat, context local.

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God. Brent. Family. Friends.

Dios. Brent. Familia. Amigos.

Déu. Brent. Família. Amics.

THE WORLD WOULD MEND ITSELF JUST FINE, IF ONLY EVERYONE WOULD DO ITS OWN DUTY WITH LOVE, AT HOME.

EL MUNDO SE ARREGLARÍA BIEN ÉL SOLO, NADA MÁS CON QUE CADA UNO CUMPLIERA SU DEBER CON AMOR, EN SU CASA.

EL MÓN S'ADOBARIA BÉ TOT SOL, NOMÉS QUE CADASCÚ FES EL SEU DEURE AMB AMOR, A CASA SEVA.

JOAN MARAGALL.

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PREFACE

"And God saw that it was very good". Scientific evidence has proved the veracity of this phrase found in Genesis 1:31. The study of the biosphere and its dynamics, it has been observed that nature is the only example of a system that works with closed cycles of matter and energy. Analyzing these cycles, revealed that human activities consist on linear processes of extraction, use and disposal, in total contrast with ecosystems functions. The above inspired the discipline of sustainability to search for alternatives to use resources in a more congruent way with natural regeneration cycles and without endangering future availability. In sum, it is a means for one day being able to say while observing the interaction between people and natural environment: this is very good.

The present dissertation "Integrated assessment and sustainability frameworks. Diagnosis, design and application of an adaptive tool" is the outcome of searching for ways to help a rich and popular concept such as sustainability to come down to the practical local arena. This resulted from my personal concern on how to counter the strong tendency of social and environmental issues to become part of a plastic discourse, that is, nothing but a headline or a one-day trending topic that ends shaping into the prevailing *status quo* rather than shaking it to steer up a transition.

In the specific context of sustainable agriculture these concerns increase when the global tendency is – at best – to substitute chemical inputs for organic ones without changing the production-consumption model. Instead, the global food market is expanding to supply the demand for *healthy food* to ease the conscience of modern societies. In the end, resources are still being over exploited and this green-washed agriculture is everything but sustainable.

Before the latter, I consider that the pathway for agriculture to be more sustainable is to refocus on the local level: decreasing dependence from external resources and increasing on-farm and local inputs to strengthen resilience. In turn, this will reinforce the sustainability of agricultural systems and the related social and natural environment.

To accomplish this objective, means for choosing between alternatives and prioritizing goals are needed. I intend to contribute the state of the art in this question with a research that aims to design and apply an adaptive and integrated sustainability assessment tool. This is a novel approach since the tool can be fully driven at local level and allows monitoring performance over time through a flexible set of indicators that are correlated to assess dynamics with a systems-based participatory approach.

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Symbols and abbreviations

CBA	Cost-Benefit Analysis
COE	Campo Orgánico Empresarial
FAO	Food and Agriculture Organization
LCA	Life Cycle Analysis
LCSA	Life Cycle Sustainability Analysis
MESMIS	Marco para la Evaluación de Sistemas de Manejo de recursos naturales incorporando Indicadores de Sustentabilidad
MuSIASEM	Multiple Scale Integrated Analysis of Societal and Ecosystem Metabolism
SALT	Sustainability assessment Adaptive and Low-input Tool
SATs	Sustainability Assessment Tools
SDGs	Sustainable Development Goals
SEDER	Sectretaría de Desarrollo Rural de Jalisco
SES	Social-ecological System

Glossary

Agroecosystem: unit of analysis formed by agricultural systems and their surrounding natural and social environments.

Framework: conceptual structure that defines a subject through its dimensions, criteria and scope.

Integrated assessment: evaluation of a subject accounting for all its dimensions. In regards to sustainability, means the inclusion of economic, social, institutional and environmental aspects.

Organic farming: agricultural management system that reduces to the minimum the use of chemical and synthetic inputs.

Systems thinking: holistic scope for the study, analysis and understanding of the parts, the dynamics and the whole of an issue.

Sustainability: discipline that studies and evaluates options for meeting present human needs while maintaining the Earth's life-support systems.

1 INTRODUCTION

1.1. STATE OF THE ART

Over the XX century, the needs of a growing population altogether with the rising and intensified exploitation of natural resources due to the industrialization of productive processes have jeopardized the ecological equilibrium of the planet. The Brundtland Report (WCDE, 1987) along with other studies (Carson 1962; Boulding 1966; Meadows et al. 1972) resulted in the conception of the sustainability approach as an attempt to raise awareness over the urgent need to preserve the environment among the general public and particularly among the scientific community.

Sustainability can be described as the capacity of a society of carrying its productive activities leaving the environment in equal or better conditions for those who come after. It is about sustaining the life-support systems of the planet (Jerneck *et al.*, 2010). The emergence of the concept highlighted a call for a shift in scientific research to be adaptive and more interrelated between different disciplines to actually provide different angles when analyzing issues in a critical way (Gallopin *et al.*, 2001).

The present thesis aims to contribute in closing a gap found in literature based in two axes: the contrast between holistic normative approach with a reductionist practice in the field of sustainability; and the lack of integrated assessment tools that are adaptive and tailored to the local context. The latter is achieved through a case study related to the agricultural sector in Jalisco, Mexico that enabled the identification of relevant elements that can generate clear inputs for stakeholders in the path towards sustainability.

Even when sustainability has clearly enhanced multidisciplinary research and out-of-the-box thinking, this expected shift has not yet occurred (United Nations 2015; Moloney & Strengers 2014). This is rooted in the ever going debate over the conceptual definition of sustainability and its differentiation from sustainable development (Mog 2004; Gallopín 2010), the number and grade of integration between its core dimensions (Burford et al. 2013; Kaivo-oja et al. 2014), the weakness or strength of its scope and implementations (Schlör et al. 2014; Böhringer & Jochem 2007), and so on. Although is now a more popular concept than in the early 90's it is far from reaching consensus and has become a discursive ingredient of researchers, governments, agencies and multinational companies around the world (Calleros-Islas 2012; Hay et al. 2014; Hugé et al. 2016; Naredo 2001).

However, sustainability has managed to stay in the spotlight in the XXI century as well which is observed in the United Nations switching from the Millennium Development Goals to the Sustainable Development Goals (Hák et al. 2016). Sustainability is now considered as a normative approach (Schlör et al. 2014) scientific discipline (Miller et al. 2013; Salas-Zapata et al. 2016), as a goal for developing policies both in the public as in the private sector (Liu 2007) and as a tool for designing and implementing transformative processes at different scales (Gallopin 2002).

The challenge is now to pass the exploratory phase of notions and debates and move towards a more practical phase. The goal is that sustainability enhances environmental protection, resilient productive processes, democracy and intergenerational equity (Vanhulst & Beling 2014).

1.1.1. Sustainability assessment

With the emergence of the concept of sustainability, almost immediately a debate on the way to measure something that is by definition incommensurable and if and how this exercise contributes to the analysis and goals of sustainability (Munda 1997; Krank et al. 2013; Zagonari 2016). Measuring sustainability is first of all, an impossible task because it is a conceptual construct, a dimension and an approach of analysis for human thought (Burford et al. 2013). This would be equal to measuring economy or nature. Second, it has another hurdle rooted in the very nature of the sustainable approach that is characterized by being complex and dynamic and therefore, immeasurable because social or natural goods and services cannot – or should not – be traded like products (Kant 2003; Salles 2011).

In contrast, sustainability because of the same complexity that defines it, calls for means to better communicate results and approaches to enable assessments and help identifying alternatives and opportunities (Mog 2004). Using the same example of economy and nature, we can measure economic or environmental indicators such as income or number of species to assess the state of the larger and incommensurable dimensions of economy and nature which is useful to choose between different options and set roadmaps towards an objective (Munda 2005; Liu et al. 2010; Hay et al. 2014).

Before the latter, a tacit agreement has been reached in sustainability research on referring to sustainability assessment instead (Pope et al. 2004; Bond & Morrison-Saunders 2011; Hacking & Guthrie 2008). This can be understood as a way to incorporate sustainability when deriving decisions and policies while it also demonstrates how unsustainable are current practices and which consequences can be expected over a given issue (Naredo 2001; Hay et al. 2014; Miller et al. 2013).

Sustainability assessment is meant to generate awareness on the existence of non-market values to consider more than money when making both individual as collective choices. In sum, it is considered as suitable to analyze the problematic regarding sustainability in order to find ways to deal with complexity, unpredictable behavior and irreversible changes (Weinstein et al. 2013; Slootweg & Jones 2011; Garcia 2005).

Several sustainability assessment tools (SATs) are being carried out with diverse purposes through deriving indicators (Meadows 1998), index aggregation (Ravallion 2011), assigning values (Sherrouse et al. 2014), impact analysis (Hugé & Waas 2011), or evaluation criteria (Munda 2004). But in order to assess sustainability related issues, the parameters must be able to deal with variables that are diverse, non-quantifiable and incomparable (Ekins et al. 2008).

Therefore, it is considered that is the integrated assessment of sustainability what makes sense to really account for goods and services that cannot be valued only through an economic scope and incorporates the real sources of value: nature and social interactions (Cornell 2011; Cano et al. 2005; Marx 1867). As stated by Poveda and Lipsett (2014), assessment methodologies that, in contrast, aim to standardize parameters to measure performance should be avoided.

1.1.2. Sustainability and productive sectors

Although rooted in previous approximations to physical constraints and natural values, around the 1960's concerns over the impacts generated by human activities settled the starting point for the sustainability approach as is now understood. Therefore and according to scientific evidence, the approach is closely tied to the productive sectors that based on national accounting are: agriculture, forestry, livestock, fisheries, industry, commerce, mining and tourism. Each one has direct effects on society and the environment of which climate change (Martin & Rice 2014), air pollution (Oxley et al. 2013), water contamination (Capellesso et al. 2015), soil degradation (Verhulst et al. 2010), deployment of non-renewable resources (Wasylycia-Leis et al. 2014; Van Der Vossen 2005), over exploitation of renewable resources (Rockström et al. 2016), fragmentation of ecosystems (Tarrasón et al. 2009) and exacerbated social inequalities (Teichman 2002; Munasinghe 2012) stand out.

Most of the abovementioned impacts are related to the agricultural sector. For this reason, it was selected as the focal object of the present thesis to design an integrated assessment tool that allows locally-driven sustainability analysis.

1.1.3. Agriculture

Agriculture is recognized as an important activity for people throughout history. It is defined as the practice of cultivating food through the management of natural resources such as soil and water (Srivastava *et al.*, 2016). It is also recognized as the human activity with greater environmental impacts: uses a third part of land surface, consumes 70% of freshwater, is responsible for a quarter of greenhouse gas emissions and employs 40% of the working force in the world (WRI, 2013; FAO, 2015; WB, 2016). Therefore, it becomes a hotspot for the enhancement or detriment of global sustainability in all its dimensions.

Agriculture works as a node where society, nature, the economy and the institutions merge in a very tangible way: societies depend on agriculture to be fed which is possible through the management of natural resources; this generates economic values, material and monetary flows, which institutions regulate directly or indirectly. The central role of agriculture is illustrated in Figure1.1.

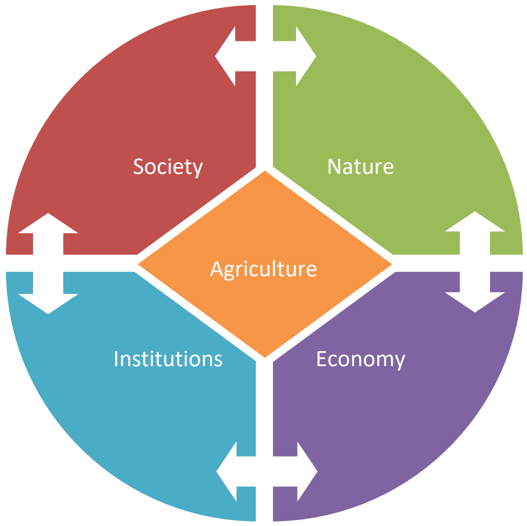

FIGURE 1. 1 REPRESENTATION OF THE RELATIONS BETWEEN SOCIETY, NATURE, ECONOMY AND INSTITUTIONS AND THE AGRICULTURAL SECTOR.

This is why it has been identified as a key target for institutions and governments worldwide as shown in the Sustainable Development Goals (SDG) that recognizes the promotion of sustainable agriculture as inter linked with ending hunger, ensuring food security and sovereignty, empowering farmers, strengthening gender equality, ending poverty, promoting healthy lifestyles, fostering sustainable production and consumption, and mitigating climate change (FFO 2015; United Nations 2012; Rico García-Amado et al. 2013). Working these issues from rural areas has a multiplying effect towards global sustainability, which is clearly stated in the Post-2015 Development Agenda acknowledging agriculture as the sector that holds together the 17 SDG.

In sum, agriculture is the sector with the highest potential to trigger the change needed to achieve these goals and going further towards greater sustainability (FAO 2016). Nevertheless, the "so aired battle of sustainability" is already lost if the need to completely reusing materials relying on solar energy is not accepted, as extensively proved by the biosphere and traditional agricultural systems (Naredo 2001). Following these statements, the *agroecosystem* concept comes in handy for this analysis.

1.1.4. Agroecosystems

Agricultural systems, even current industrialized ones, are closely linked to nature not only for managing natural resources at farm level, but because these resources are related to surrounding ecosystems and form part of a whole where biological and ecological processes and functions take place. This whole also relates to society and is defined as an “agroecosystem”.

Conceptually, the term is derived from the social-ecological system (SES), an approach that is based on the analysis of society – including economy and institutions – and ecology as one single system (Ostrom, 2009) instead of the “parceled” vision that has prevailed in science for more than two centuries (Gallopin *et al.*, 2001; Naredo, 2001; Munda, 2004) especially since the hegemony of neoclassical economics (Costanza, 2003).

SES theory states the dependence between economy, society and the environment since human beings are not isolated from nature and the latter is one of the strongest influences on social development (Ostrom, 2009). In the same way, the economy is not a closed environment as conceptually formulated but a system that works within a society which interacts with surrounding nature. Their interrelation is so close that makes little sense trying to understand these dimensions separately, and therefore, SES becomes the object of analysis (Wilson *et al.*, 2013; Frey, 2016).

Agroecosystems are then understood as agriculture based SES: agricultural systems embedding social, economic, institutional and ecological dimensions and dynamics. This concept works as the basic unit of analysis of my research for the suitability of a systems-based approach for addressing sustainability complex and interrelated issues. It is particularly helpful to assess agricultural practices given the huge importance of this sector regarding social and environmental impacts.

1.2. Objectives and methodology

1.2.1. Identified research gap

A thorough bibliographical research was conducted throughout the present thesis which was necessary due to the transversal nature of the subject. Over 300 documents were consulted (70% journal papers; 30% official reports and institutional web pages) and a total of 230 references are directly cited in the chapters. This large amount of bibliographic resources allowed the identification of a research gap regarding two main issues: 1) the translation of the rich and multidimensional sustainability theory into results and applications that fulfill these attributes; and 2) sustainability integrated and adaptive assessment tools that can be applied and driven at local level.

More specifically, there is still a long road for sustainability to go from science to actions through a holistic perspective, from a discursive element to a policy target that shapes decision-making (Cohen *et al.*, 1998; Astier *et al.*, 2011; Burford *et al.*, 2013; Sala, Ciuffo and Nijkamp, 2015; Kliskey *et al.*, 2016). And even when many tools to are available, there is a need for tools that assess if present performance is moving towards or backwards in terms of sustainability that are context-specific and flexible enough to be applied locally from start to finish: from the identification of elements of the system, variables selection, measurement of parameters to the assessment of results and monitoring (Singh *et al.*, 2009; Ostrom and Cox, 2010; Sharifi and Murayama, 2013; Poveda and Lipsett, 2014; Strunz *et al.*, 2014; De Olde *et al.*, 2016).

1.2.2. OBJECTIVES

The main objective of this thesis is to design and apply an adaptive and integrated sustainability assessment tool that can be driven at local level and allows monitoring performance over time through a flexible set of indicators and a participatory approach. The hypothesis is that if a tool for integrated assessment includes a systemic framework then, is useful for consolidating the sustainability approach to drive decision-making processes and bringing tangible results at local level.

To achieve this general objective, the research follows two main research lines:

1. The study of sustainability frameworks aiming to observe how international institutions characterize sustainability and if this is translated in clear plans for action.
2. The review of sustainability assessment tools in order to identify those that enable in a consistent way the put to practice of the principles of sustainability.

The following specific objectives were also identified:

1. Analyze sustainability frameworks to select those that better reflect the interrelated and multiple dimensions of the concept to consolidate the sustainability approach.
2. Carry out a diagnosis on sustainability assessment tools that generate clear inputs for guiding decision-making processes, policies and actions towards sustainability.
3. Incorporate a systemic sustainability framework into an integrated assessment method in the design of an adaptive tool for assessing sustainability at local level with low input requirements and high level of flexibility.
4. Apply the tool in a case study conducting field work to gather first-hand information and directly observe and evaluate results at local level.

1.2.3. Structure of the dissertation

The specific objectives also correspond to the chapters that result from an iterative process. This allowed more tangible results that in turn led me to identify the elements that were needed for assembling the tool. Accordingly, the methodology of my research went from the whole to the parts and back to the whole (Montessori, 1909). This meant going from the conceptual and more theoretical research on sustainability frameworks and assessment methods to the definition of the case study that through field work allowed me to identify the elements of the analyzed system and the need for a local perspective. Then, I assembled these elements into a sustainability integrated assessment tool that in turn allowed returning to sustainability analysis through systems thinking as shown in Figure 1.2.

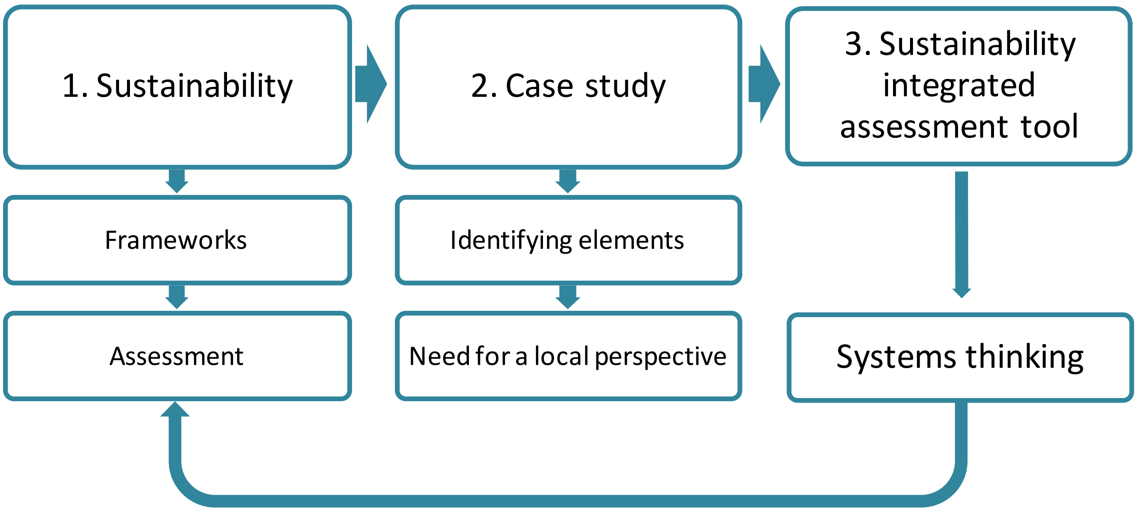

FIGURE 1. 2 PROCESS FOLLOWED THROUGH CONDUCTED RESEARCH.

The thesis here presented is structured as follows. The introduction presented in this first chapter starts with an overview of the current state of the issue in four main components: sustainability, sustainability assessment, agriculture and the agroecosystem approach. A second section states the methodology emphasizing the need for research in the field of study: means to assess progress towards sustainability at local level.

The following chapters are part of the peer reviewed literature. Publication details are provided in the cover of each chapter.

Chapter two is dedicated to the general analysis of sustainability frameworks. It is focused on how international institutions and researchers are translating the concept into guidelines and at what extent these guidelines actually direct programs and projects.

Chapter three reviews sustainability assessment methods in order to detect the degree in which they reflect the multiple dimensions of the approach and how understandable is their input for stakeholders for sustainability to permeate decision-making processes.

The fourth chapter describes the case study entering in the specific characteristics of the agricultural sector through the assessment of the “Project of promotion and development of organic agriculture for grain producers in Jalisco, Mexico”. This case study included on-field work and non-structured interviews that I personally conducted in two field trips with a total duration of 45 days.

Chapter five describes the integrated and adaptive tool that was designed to assess sustainability at local level through its application in contrasting a conventional management agricultural system with an alternative one from the abovementioned project.

Following the process described above, the sixth chapter is an effort to get the whole back together, which is achieved through the incorporation of elements from systems thinking approach to get as close as possible to a dynamic assessment within the limits of the present research.

Finally, general conclusions are presented in chapter seven to contrast results with the aims and objectives altogether with future research lines and applications. This is meant to allow evaluating the level of congruence achieved between the aspirations that shaped my dissertation at the beginning and final results.

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2 THE FRAMEWORKS OF SUSTAINABILITY: APPROACH, DIMENSIONS AND APPLICATION GUIDELINES

ABSTRACT

This chapter presents a review of a selection of the most relevant sustainability frameworks that are applied in worldwide institutions at international, national and academic scales. The latter is meant to identify their influence on the scope assessment and general concretion of the sustainability approach. The aim is to clarify some of the possible ways to consolidate the operational capacity of sustainability at different levels without losing its holistic approach.

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2.1. INTRODUCTION

The consolidation of sustainability as a concept was a result from the emergence in the late past century, of several scientific publications that underlined the necessity of considering factors other than economic growth to assess development (Carson 1962; Boulding 1966; Meadows et al. 1972; WCDE 1987; Max-Neef 1991; Sen 1998).

Since then, it has become evident that both the world's resources and the environmental capacity of natural systems are far from being inexhaustible (Kosoy *et al.*, 2012) and that human activities are not only generating irreversible changes on global ecology but also have adverse consequences for human kind (Lenzen and Schaeffer, 2004). Therefore, it is clear that there are limits that should be considered in the way resources are exploited so that the capacity of recharging their natural stock is not exceeded, though nowadays the exploitation rhythm is unsustainable in many cases (Novo, 2006).

This recognition underlines the importance of ecosystems functionalities and services as fundamental for maintaining the Earth's cycles, which emerges as a critical issue before climate change extreme events. Accordingly, the inclusion of future scenarios and probability studies is not only important but mandatory to have a minimum preparation towards events yet to come (Mermet, 2008).

Therefore, the need to incorporate the concept of sustainability in any analysis is now indisputable (Kajikawa, 2008; De Felipe *et al.*, 2009). Considerations on this issue have revealed that effects derived from human activity such as pollution or ecosystems degradation as obstacles for development. Hence, the inclusion of sustainability guidelines has become necessary in the analysis of economic processes (Munasinghe, 1993).

The concept of sustainable development is generally defined as the development that satisfies current needs taking into account future ones (WCED, 1987). However, while the minting of the term itself highlights the unsustainability of the current dominant model, this acknowledgement has rarely been accompanied by proportional measures to make the concept operative reflecting a lack of conceptual concretion (Antequera et al. 2005). It is also considered as an ambiguous concept, a non-scientific method and therefore, the results obtained from this approach are not precise (Norton 1992).

Regardless the lack of clarity associated with the term *sustainable development* and its implementation, as stated by Gómez (2004) this provides a wider scope under which issues can be addressed by enabling the incorporation of different elements and approaches as well as being applied among different fields. All this would not be possible with a precise and bounded definition of the topic.

Moreover, the present many-sided environmental and socioeconomic challenges need the adoption of an adaptable approach that goes across diverse scientific disciplines to be addressed (Gómez Sal, 2004). Hence, sustainability as a complex and systemic dimension allows the holistic analysis of economy, society, culture and environment as interrelated parts of a whole, allowing the application of interdisciplinary and systemic methodologies (Aznar Minguet and Ull Solís, 2009).

In the same way, the complexity of the sustainability approach is due to the needed for a simultaneous analysis of the diverse social, cultural, economic, institutional and environmental aspects to achieve progress in this knowledge area (Virji et al. 2012).

Sustainability gains importance when the present crisis scenario observed at different levels and scales around the world is taken into account. The reason is that crises promote shifts and adaptation strategies such as the construction of spaces to allow the discussion and reflection on the role that sustainability research and applications have (Correa-ruiz and Moneva-abadía, 2011).

Just like conceptual vagueness provides a greater wideness to the application and study of sustainability (Boström, 2012), the ongoing crisis is actually an opportunity to generate new possibilities, capacities and tools to open diverse windows for policy making. This also implies and even requests the inclusion of resilience, a concept that goes beyond comprehending the capacity to absorb impacts of a system without compromising its functioning basis. Resilience includes a fundamental issue for sustainability: change potential and possibilities that unfold through perturbations (Folke, 2006).

Following these statements, sustainability reveals that development is no longer another word for growth but a multifaceted, interdisciplinary and systemic pathway towards the equilibrium of all its dimensions that correspond to the main spheres of human and planetary existence: social, ecologic, economic and institutional (CEPAL-ESALC, 2004).

All these considerations on the conceptual development of sustainability reveal that many positive outcomes can be expected when adopting a sustainability approach to any subject and outline working towards a more unified and solid scope to enhance its inclusion. One way to do so is to review the existing visions, applications and evaluation methods on sustainability (Mog, 2004).

Taking this into account, the aim of this chapter is to compare some of the most relevant frameworks of sustainability used worldwide through their practical and conceptual assumptions. The comparison is made in a non-systematic way with the main goal of building a commented compilation of initiatives to take sustainability into account as a decision-making driver at institutional level. It is expected that this exercise helps enhance further contributions on the operational capacity of the sustainability approach.

The conducted analysis started with a review on what some of the major global institutions understand by sustainability since this defines the basis for assessment and measurement. Second, the contribution of each framework to the concretion of sustainability is contrasted. In this case, the order of the factors does affect the results meaning that the context and approach to sustainability of each framework defines the outcomes. Finally, results are commented and some guidelines are drawn as proposals to enhance the capacity of sustainability to address concrete problems.

2.2. SUSTAINABILITY FRAMEWORKS

Sustainability was established as a policy making discipline at international level in the nineties through the global consensus reached in the first United Nations Conference on Sustainable Development (Earth Summit) that took place in Rio de Janeiro, Brazil. Later, in the World Summit on Sustainable Development in Johannesburg 2002, a Plan of Action was signed by a large number of governments in order to reaffirm their commitments (PNUMA, 2011).

These international events helped creating a new vision on development that promotes the creation of joint science and tools for transdisciplinary assessment. Thus, sustainability has become a way to answer the needs of society without compromising the stability of the systems that support life on the planet (Jerneck *et al.*, 2010). Also, allows being implemented across different scientific fields enriching analysis and applications (Lang *et al.*, 2012).

Nevertheless, as stated before, there is still low consensus on the actual meaning of sustainability as a concept. The fact is that it is still under development as a scientific discipline, which has been broadly debated and criticized in two main streams: first, the lack of clear principles that can lead research and knowledge progress; and second, the few built-in capacities to actually implement sustainability on specific cases (Lang et al. 2012; Salas-Zapata et al. 2012).

As a result, there is no single framework of reference on how sustainability analysis is conceived or applied through a certain methodology (Olalla-Tárraga, 2006). Each country, institution or research group implements the theoretical framework that best suits their needs and targets.

The difficulty of integrating the sustainability approach on a single conceptual framework is because is driven to seek for solutions to problems with complex nature that are structured through several interconnected branches. In consequence, an interdisciplinary and integrated scope must be settled to enable and encourage a cross-flow of information and experiences among stakeholders – governments, companies, communities – with different and often conflicting interests (Virji et al. 2012).

There are several projects among the literature that empirically apply sustainability in an interdisciplinary way. But this is made in such different ways that the application of its principles and key components also gets complicated (Lang *et al.*, 2012).

Another aspect emerges at this point related to the dimensions of sustainability generally environmental, social and economic. In the reviewed literature, it was noted that there is still a low level of integration between these dimensions. As a result, they are viewed as exclusive sets, when they are actually intersected (Naredo, 2001; Costanza, 2003; Fenech *et al.*, 2003; Thampapillai and Thangavelu, 2004).

The social dimension is the least integrated in the frameworks of sustainability mainly because means dealing with greater complexity. More efforts have been made towards defining its own meaning than to its implementation in sustainability assessments (Murphy 2012; Psarikidou & Szerszynski 2012). This demands attention since a broader inclusion of the social dimension enriches and better supports sustainability as a whole and helps its implementation in decision-making or policy design among different fields (Farber et al. 2002; Atria 2003; Nieves Rico & Dirven 2003; Tippett 2005; Calleros-Islas 2008; Costa & Kropp 2013; Virji et al. 2012).

These factors lead to the challenging task of going from a dissected to an integrated assessment of sustainability and its dimensions. This task has been undertaken over the years from different scopes by scholars: human capital and capacities perspective (Sen, 1998); natural capital assessment (Daily *et al.*, 2000); through a resilience and systems-based approach (Folke, 2006); the study of sustainability indicators and ecological-distributive conflicts (Martinez-Alier, 2006); the review of sustainability as a science (Kajikawa, 2008; Jerneck *et al.*, 2010); through a holistic perspective (Gallopín, 2010); or the interrelation between people and natural conservation (Linkies, 2011).

On the bright side, from the beginning sustainability has been a bridge between social and natural sciences allowing a joint search for solutions and alternatives to the complex challenges currently encountered (Jernek 2011). Thus, as stressed by Folke (2006), sustainability makes it easy to consider resilience as a key factor generating a change of perspective: from trying to control and stabilize the system to managing its own abilities to cope, adapt and transform before changes or disturbances.

The latter highlights the adaptive and dynamic character of sustainability, making the thinking-outside-of-the-box more important to generate applied and useful public knowledge that has an impact in our daily lives (Marsden, 2013).

2.2.1. Review of sustainability frameworks at the international level

Considering that there are almost as many sustainability frameworks as possible applications, it is important to clarify the limits of the scope and how the reviewed ones were selected. The present review is made to observe how deep is the impact of the sustainability approach at different levels in some of the main institutions regarding level of influence (international organisms, national governments and academics).

The premise is that there is a direct relation between the adopted framework and the impact of sustainability in the decision-making and policy design processes. There are many other sustainability frameworks at regional or urban scale that could be considered (Olalla-Tárraga, 2006; Veisi and Toulabi, 2012; Schwanitz, 2013), but they are more spread among literature and refer to more specific issues. Because of the limitations of the present analysis these were not accounted.

The following criteria – ordered by importance – were considered to select the analyzed frameworks: a clear definition on sustainability has to be manifested. This definition must be made through concrete elements or dimensions; and within the framework there is either an evident or an implied contribution to sustainability science.

Selected frameworks are organized and visualized in Table 3.1. Here, a list of those that were analyzed is shown. The analysis was made based on three aspects that correspond to the selection criteria: a) the definition of sustainability adopted; b) the dimensions considered; and c) the guidelines for implementing and assessing sustainability.

Selected frameworks are placed in descending order of the scale at which each corresponding institution works. In the first group are the international institutions frameworks: United Nations Organization (UN), Organization for Economic Cooperation and Development (OECD), European Union (EU), Inter-American Development Bank (IDB), Initiative for Latin America and the Caribbean (ILAC) and the Sustainability Assessment of Latin American and Caribbean Economic Commission for Latin America and the Caribbean (ESALC for its Spanish acronym). The second group is formed by frameworks adopted by national governments of: Germany, Spain, United Kingdom, Switzerland, New Zealand, Canada and the United States of America. In the third group, theoretical frameworks from the academic sector are found: Meadows (1998) and Bossel (1999). It is worth to mention that Latin American countries majorly adopt the ILAC or the ESALC framework and therefore are not mentioned in particular but were reviewed.

TABLE 2. 1 SUSTAINABILITY FRAMEWORKS ANALYSIS.

SUSTAINABILITY FRAMEWORKS			
Institution	*Sustainability approach*	*Considered dimensions*	*Assessment*
UN	SD* promoted through technical cooperation and capacity building at international, regional and national level	• Economic • Social • Environmental	Integrated in policy making with participatory approach Progress evaluated under Johannesburg Plan
OECD	Focus in environmental issues linked to climate change to help its integration in sectorial policies	• Economic • Social • Environmental	Environmental accounting and indicators on conomic growth's pressure on the environment
EU	SD: contribute to a deeper change, avoiding irreparable damages and creating a prosperity, equity and wellfare future scenario	• Climate change and clean energies • Sustainable transportation • Sustainable consumption • Global poverty	Corresponding with dimensions targets are fixed and compared with present state
IDB	SD: maximizing positive impacts at environmental and social levels while minimizing risks and negative impacts	• Economic • Social • Environmental	Develope institutional and regulation frameworks for sustainability investments
ILAC	SD: satisfy human basic needs and aspirations including future generation ones based in natural capital	• Biological diversity • Water management • Vulnerability, human settlements and sustainable cities • Socioeconomic and institutional	Indicators at national and regional level that respond to local particularities
ESALC	Systemic sustainability approach: equilibrium between subsystems and observes flow's unequities	Socioecological system: • Institutional, environmental, social and economic dimensions	Systemic and integrated evaluation using environmental, social and economic indicators
Germany	SD: each generation solves its own problems instead of passing them to the next one	• Intergenerational equity • Life quality • Social cohesion • International responsibility	Corresponding with dimensions targets are fixed and compared with present state
Spain	Driving Forces Model: Pressure, State, environmental Impact and Response (FPEIR) developed by the European Evironment Agency	• Economic • Environmental and territorial • Governance and sustainability • Global	Integrated evaluation of sustainability dynamics through selected indicators
United Kingdom	Stimulate economic growth, diminish deficit, maximize wellbeing and protect the environment without affecting future generations	• Economic • Social • Environmental	SD indicators battery based on experience and wellbeing measures
Switzerland (MONET)	SD: cover the needs of the present without compromising those of the future (Brundtland Report) plus World Bank's capital stock model	• Social solidarity • Environmental responsability • Economic performance	Sustainability: when development mantains and reafirms capital in all dimensions
New Zeland	Capital stock model: seeks to maintain through time the natural, economic and social basis	• Social and human • Environmental • Economic	Sustainability: when development mantains and reafirms capital in all dimensions
Canada	SD: cover the needs of the present without compromising those of the future (Brundtland Report)	• Economic • Social • Environmental	Canadian Environment and Sustainability Indicators (CESI)
USA	SD: cover the needs of the present without compromising those of the future (Brundtland Report)	• Economic • Social • Environmental	According to dimensions, principles, themes and indicators are defined
Bossel	SD: human and natural systems co-evolution; 6 derived subsystems	• Human system: social & individual development + government • Support and help system: infraestructures + economy • Natural system	Viability depends on the correct functioning of each subsystem
Meadows	SD: natural, social and constructed capital approach; based on Daly's triangle and Max-Neef pyramid	• Wellbeing • Social and human capital • Constructed and human capital • Natural capital	Integrated sustainability indicators to evaluate performance

*SD= Sustainable development.

In addition to frameworks showed in Table 3.1, the inclusion of Brazil, India and China, countries with high developing and growth rates was also considered. However, their approach to sustainability is not clear enough to be assessed and therefore was not included in the analysis.

Although Brazil has an interesting definition of sustainability in the dimensions of economic efficiency, social justice, sustainable rural development and ecological prudence, a clear framework and assessment criteria are missing.

China is directing efforts towards environmental protection and continuous development through industrial process efficiency and productivity under a green strategy, but currently with no mention to sustainability. This seems somewhat predictable if we bear in mind the country's position against some global-scale environmental initiatives such as Kyoto's Protocol.

India counts with an Institute of Biosciences and Sustainable Development that works at national level and focuses efforts on the conservation and management of the abundant biotic diversity of the Indo-Burma region as key for development. However, it does not have a clear approach to sustainability.

2.2.2. Preliminary findings

As observed in this review, the currently dominant visions of sustainability are still under the sustainable development concept. The latter contrasts with the wide adoption of the concept as a guideline for decision-making and policy design processes.

Out of the fifteen analyzed frameworks, only four expressed sustainability from a holistic perspective and not only being implied in sustainable development: the IDB, the ESALC, Spain and New Zealand frameworks. However, a difference should be made among sustainable development approaches adopted by the OECD, the UK or the U.S., and those adopted by UN or countries such as Switzerland and Germany. The reason is that while the former are focused on economic growth, the latter take into account at the same level intergenerational equity, solidarity or capacity building.

Even more differences are observed in the sustainable development approach adopted by Bossel (1999) and Meadows (1998) that consider the dual nature of the term: the development, in its most global sense as a measure of human welfare, and linked to the sustainability of the whole system taking limits into account. Under a systemic approach, development is not considered as a synonym for growth. Much less when it comes to assessing sustainable development including aspects such as equity, life quality, adequacy of resources or efficiency in the analysis (Meadows, 1998).

As for the means of implementation and assessment, some differences are also evident in the selected sustainability frameworks. Institutions that have been conducting sustainability assessments for more time, have established their own set of indicators. Even countries within the EU are not using the same indicators. This was not unexpected since the description of sustainability itself varies among analyzed institutions. Even so, it is noteworthy that in all cases the need to measure progress in terms of sustainability was clearly established, empirically evidenced and considered necessary for continuous evaluation processes such as reports and other accounting systems.

2.2.3. Suitability of a systems-based approach

Natural and socioeconomic systems are in constant change. Consequently, a systems based approach is best suited to assess them and to the design of methods to identify key elements and interrelations as well as evaluate trends and flows between them (Gallopín, 2010). Thus, a systemic approach highlights that what happens to one part affects the whole of the system because of the synergies and other forms of relations between the parts (Novo, 2006). Then, when seeking sustainability frameworks that allow concrete results and impacts decision-making the ones made under a systems based approach stand out.

Accordingly, from the analyzed frameworks the best suited for the objective of this chapter are the ESALC and IDB in Latin America (at the regional scale), Spain and Germany in Europe (at the national scale), as well as the ones presented by Meadows (1998) and Bossel (1999) (conceptual-academic scale).

However, some of these frameworks make it more clearly than others. The framework used by the IDB although built on the basis of water availability as a limiting factor for the system, does not correspond to the definition of targets and evaluation methods. The cases of Germany and Spain are both well endorsed with a set of indicators and help in alternatives and results evaluation, but mechanisms to land proposals and goals at local level are missing. In conclusion, in order to gain a greater level of concretion and integration of sustainability in general and its implementation in particular, the more appropriate frameworks are the ESALC, Bossel (1999) and Meadows (1998). These frameworks have the potential aspects to generate a useful tool for the integrated assessment of sustainability.

2.3. Conclusions

Reviewing sustainability frameworks enabled to overview the present state of the sustainability approach at different scales. The review was made under the premise that frameworks open a pathway to strengthen the operational capacity of the sustainability approach based on their capacity to structure, interpret and integrate information to help decision-making processes. Through this exercise, the need for improving the approach at operational level was remarked and is explained in three main points.

First, the most widespread interpretation of sustainability is still the one linked to development generally through three dimensions: social, environmental and economic. However, this is not widely reflected on the way policies and decisions are designed and implemented. This is particularly evident at national scale where paradoxically, it would be more necessary since the decision-making process are supposed to meet short and medium term goals.

Second, though there are frameworks that result from a work thoroughly done and some very interesting insights, it is considered that a common base should be built if a greater sustainability of the socio-ecologic system as a whole is to be achieved. Adopting a systems-based approach could become this common base since it is necessary to overcome the challenges faced worldwide and to address the complexity of sustainability related issues.

Third, it was observed that to consolidate the sustainable paradigm and its operational capacity, sustainability dimensions approach should be less fragmented. Among the reviewed literature this fragmentation was present usually at the implementation and valuation stage, since it is more achievable to assess them separately. The integration of the core dimensions of sustainability in any consideration is mandatory, especially concerning the social dimension. This need for integration can also be covered by adopting a systems-based approach.

One of the possible lines to help in this consolidation process is to conduct a more extended review on ways to summarize the complexity of the services received from society and nature to evaluate them and therefore facilitate decision-making processes. The assessment of sustainability through integrated methodologies is proposed as a way to achieve this

Another line to continue research in this area is merging methods of integrated assessment and the analysis of sustainability frameworks. This exercise can help including both elements into a concise tool for assessing sustainability in a broader sense towards problem solving.

Evidently, there is still much to do in this field. Here, only one of many ways to provide more practical outcomes of sustainability is explored. In conclusion, it is not desirable to simplify or uniform sustainability approaches but to make their results and principles as accurate and implementable as possible to generate positive outcomes for present and future generations.

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3 Sustainability in practice: integrated assessment to support policy and decision-making processes

Abstract

Sustainability has been recognized, when facing multifaceted decision and policy making processes, as a discipline that broadens the scope under which issues are taken into account. This is considered important given the complex and interrelated challenges faced by societies nowadays. However, it has been found in literature that the sustainability approach still has several obstacles to tackle, from the weakening of its discourse to the lack of real influence and low consensus on its meaning and practice. To reinforce the operational side of sustainability, several methodologies have been designed and implemented over the years with two main shortcomings: an inability to assess sustainability issues as a whole and more specifically, a lack of practical steps that can be included on a day-to-day basis. Integrated assessment emerges as a possible way to summarize the complexity of studying issues from a broader perspective but it is applied in different ways with diverse outcomes that require careful examination. These outcomes are compared by analyzing four integrated assessment tools: life cycle assessment, cost-benefit analysis, stakeholder analysis and multiple scale integrated analysis of societal and ecosystem metabolism. The aim is to observe and determine the degree to which they contribute to the consolidation of the sustainability approach and how they support decision-making processes. It is intended that this exercise help build a diverse yet deep common base for further conversation that will facilitate the process of searching and selecting alternatives to drive socio-ecological systems towards a more sustainable future.

Keywords: sustainability approach, consolidation of sustainability, integrated assessment, policy making, decision-making.

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3.1. Introduction

Narrowly described as covering present needs without compromising those of the future (WCDE, 1987), sustainability has become an important pillar when facing development issues. The present twofold scenario with climate change on the environmental side and poverty and economic crisis on the socioeconomic one, makes it even more imperative that we consider equity between and within generations in order to achieve more sustainable cycles of human progress (Biermann *et al.*, 2012). As awareness of resource scarcity grows, tools and methods for determining the best way to use them are needed.

However, there is no one or best way but several ones with different implications and consequences making the task much more complex. Success is not achieved by simply incorporating a sustainability approach into processes where many different interests and goals are at work. Missing still are the practical steps to actually address real issues. Searching for means to integrate sustainability into the processes that lead to real-world actions is necessary for its core principles to drive actions that will result in more consistent decisions, policies and a more balanced development.

3.1.1. Measuring sustainability

Long Long has been discussed how measurement methodologies contribute to sustainability (Krank et al. 2013). Some consider measuring the immeasurable as a way to market natural and social goods and services so that they can be traded like any other product (Salles 2011; Krank et al. 2013), while others see that sustainability needs to be evaluated in order to simplify its complexity and generate more accurate assessments (Costanza 2003; Raymond et al. 2009).

While both considerations have pros and cons, sustainability as a discipline still needs to reinforce its operational side. There is a lack of consensus on its definition and practice, showing contradictions between its conceptual and normative conception. The interdisciplinary and diverse conceptualization of sustainability contrasts with its more reductionist practice related to predictive statistics (Benessia et al. 2012). This contrast has a dual effect: on one hand it gives a broader spectrum for sustainability to be applied in different fields (CEPAL-ESALC 2004; Lang et al. 2012) while on the other, makes it harder to get reliable, provable results and therefore receive consideration as a scientific approach (Ekins et al. 2008; Hak et al. 2012).

Methods that are used to assess sustainability issues have different outputs which are the result of different ways of understanding and applying sustainable parameters and principles. Thus, the challenge of dealing with diverse, non-quantifiable and even incomparable variables should be taken into account when evaluating socio-ecological systems (Ekins et al. 2008).

3.1.2. Aims and objectives

The present article analyses four tools to identify how they enable the integrated assessment of sustainability and how they influence decision-making processes. After beginning with an introduction to sustainability measure, followed by the aims and objectives of the paper, section two briefly presents the implemented overall methodology, the selected approach and its justification. Section three overviews the integrated assessment of sustainability and its role in policy design and decision making processes by reviewing four commonly used tools in order to identify how they work and what are the needs and possible pathways to help in the consolidation of the sustainability approach. Section four discusses the results which are then followed up by some conclusions.

3.2. Methodology

Integrated assessment has emerged as a way to account for goods and services usually overlooked by the conventional conception of value. It also considers important aspects of sustainability such as ecological and social justice (Costanza, 2003; Cornell, 2011) and adds them to the search for efficiency. This approach is based on the value of biodiversity and the other factors that provide services needed for human kind within an ecosystem (Folke, 2006), observing that the real sources of wealth are the biosphere and the social dynamics that occur within it. Therefore, even if they are outside the market, these are the real sources of value (Cano, Cendra and Stahel, 2005).

There is a great difficulty in managing something without valuing it first (Liu *et al.*, 2010). Before this, as stated by Meadows (1998) “we measure what we value, but we also get to value what we measure” (Meadows, 1998). Sustainability assessment can help make people conscious of values invisible to market-oriented economics, considering more than just profit when making daily life decisions that can dictate the pace at which a society develops. It also strengthens social capital, reduces the degree of dependence on the exterior and helps to cope with external forces such as climate change, top-bottom policies or economic crisis (Sharifi and Murayama, 2013).

3.3. Integrated assessment, policy design and decision-making processes

The actual state of sustainability assessment is characterized by the existence of several tools and methods carried out by different users with diverse backgrounds and purposes. There are as many sets of sustainability indicators as organisms and research groups that develop and implement those sets (Hak, Kovanda and Weinzettel, 2012), showing the low level of commonality that is rooted in the lack of consensus on the very concept of sustainability (Wiek et al. 2012; Salas-Zapata et al. 2012).

It should be noted that integrated assessment methods are the function of the adopted vision of sustainability and this determines the kind of policies and actions derived from these methods. Therefore, the degree to which these exercises actually contribute to sustainability depends on the goals and agendas of researchers and their vision of sustainability.

3.3.1. Policy and decision-making

While making decisions, policy makers try to undertake complex issues related to sustainability with certain standards. At the same time, governments must negotiate with different actors that have different perceptions of a problem. Along the process, the challenge is to find a balance between getting enough support from the parties involved and achieving goals (Runhaar, Dieperink and Driessen, 2006).

Decision theory gives three different ways of making decisions according the level of definition and understanding of the process: structured, semi-structured and unstructured (Liu, 2007). The majority of environmental and social policy decision-making processes tend to be unstructured and interrelated. However, they are treated separately by researchers as can be inferred by the methods they implement, in contrast with the broadly accepted conceptualization of the socio-ecological system (Hiedanpää, Jokinen and Jokinen, 2012). These are the reasons for studying how integrated assessment can enhance and facilitate decision-making processes, which in turn contributes to catalyze efforts towards sustainability.

3.4. Methods

Selected tools (Figure 3.1) are in accordance with the three main dimensions of sustainability. Hence it is possible to compare the way in which they actually contribute to the consolidation of sustainability as a whole and to each one of its branches. The focus here is directed to the degree in which integrated assessment tools can provide useful information and enhance decision-making and policy design processes as an indicator for strengthening the sustainability approach.

With many possible options, selected methods may not be the most representative in some aspects, but regarding the objectives of the present paper they were considered as suitable because they allow both quantitative and qualitative analysis. Some have an explicit integrated perspective while others can be implemented in different ways to provide a more holistic view.

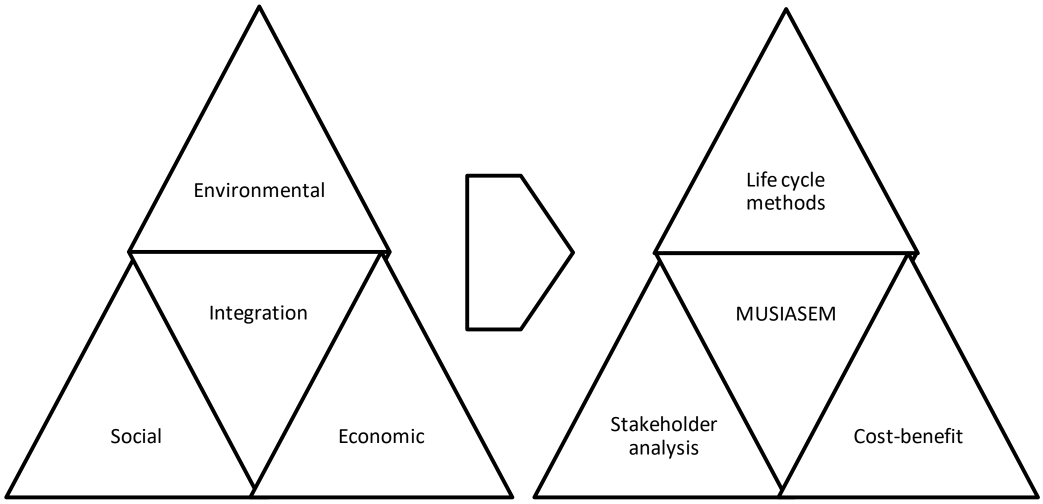

FIGURE 3. 1 SELECTED INTEGRATED ASSESSMENT TOOLS

3.4.1. LIFE CYCLE METHODOLOGIES

Over the last 20 years, life cycle methods have become part of the most popular environmental assessment tools for evaluating and describing environmental effects caused by products, processes or activities (Shields, Blengini and Solar, 2011). Life cycle assessment (LCA) is the basic tool among them and it is defined as the analysis of the processes of extraction, use, recovery, emissions and waste generation of a product or service (Klöpffer, 1997). There are other life cycle methods that complement this scope such as: social life cycle assessment, which includes effects on poverty levels; life cycle costing, accounts the monetary costs or benefits to a defined stakeholder; and life cycle sustainability assessment (LCSA), that analyses the extent to which the life cycle of a product affects the meeting of needs for both present and future generations.

Interest is placed on how life cycle methods can be used to assess sustainability while aiming for simplicity. LCSA is the most adequate method for it focuses on whether a product is sustainable or not in terms of how its life cycle affects the environment, the levels of poverty among current generations and stock changes for future ones (Jørgensen, Herrmann and Bjørn, 2013). Helps to visualize what the production and consumption model that prevails globally involves. However, it has a high data requirement and has low incidence in policy developing for the difficulty to communicate its results. It is a business-oriented method that focuses on the ecological sphere still lacking a full incorporation of sustainability (Jones, Rose and Tull, 2011).

3.4.2. Cost-benefit analysis

Among the most commonly used economic evaluation tools, the cost-benefit analysis (CBA) focuses on assessing whether a program, policy or a specific investment is financially viable. Therefore, it is useful for determining if benefits can outweigh costs and expresses both the negative as well as the positive effects a certain action can produce in monetary terms (Runhaar, Dieperink and Driessen, 2006).

CBA consists of the identification and economic valuation of current and future costs and benefits of a project; determining the rate of discount; time horizon fixation; developing one or more methods to bring the costs and benefits to present values; and estimating the relationship between the costs and benefits (Munda, 1996, 2004). It uses mechanisms such as grants and subsidies accounting or shadow prices to correct market errors (Cordero *et al.*, 2006). Usually such studies are used in project evaluation and are typically expressed in terms of the willingness to pay for a specific good or service (consumer preferences).

The major strength of CBA is that it enables the evaluation of different outcomes by translating them into monetary units. Therefore, tangible and intangible, direct and indirect costs and benefits can be assessed in one single analysis. Here is where the integrated character of this instrument is shown.

However, this same strength has been considered the weakest point of CBA. The reason is that by adopting a unidirectional approach with a single criterion assuming all things involved as commensurable, it is impossible to accurately reflect the complexity of interrelated systems, such as socio-ecological systems (Falconí and Burbano, 2004). The difficulty of measuring and monetizing some aspects can lead to its disregard.

3.4.3. Stakeholder analysis

Stakeholder analysis enables the identification of the group or network existing regarding a specific issue, to face multiple interests and goals when making decisions or developing policies. It has evolved from its political economy and business management background to include fields such as decision theory, multiple criteria analysis and social participatory approaches (Grimble and Wellard, 1997).

This method helps to understand how a system works while assessing how changes can affect the system. The latter is achieved by the identification of key actors, their interests and perspectives at different levels aiming to understand interactions within development and environmental issues.

One of the methods in stakeholder analysis is the matrix of asymmetric adjacency. It consists on the identification of main social actors within the analyzed socio-ecological system and is based on the perspective provided by the stakeholder according to the intensity and nature of the interaction with other actors. Reflects the nature of relationships between actors represented by assigned values that show the degree of interaction, whether it is positive or negative, etc. Also, ranges are established in terms of the intensity of the interaction between actors and the particular system in the studied area, identifying groups whose decisions and actions directly affect the local ecosystem and that in turn, are affected by how the ecosystem is managed (Rescia *et al.*, 2008).

Stakeholder analysis works as a practical methodology to identify solutions and design policies; it offers a holistic view, can be applied to different subjects and consumes relatively low quantities of time and resources. However, it has some limitations in providing practical answers and does not ensure a strong participation of involved actors (Runhaar, Dieperink and Driessen, 2006).

3.4.4. Multiple scale integrated analysis of societal and ecosystem metabolism (MuSIASEM)

The MuSIASEM method arises from the concern of information transfer between levels when facing multiple scales and dimensions in complex interrelated issues, where usual quantitative tools are found to fail. It responds to the question of how to assess complexity by adopting a holistic metabolism approach of the socioeconomic and ecological systems (Madrid, Cabello and Giampietro, 2013).

The metabolism of energy and material flows is analyzed following the semantic criterion of fund and flow elements. Fund elements show the characteristics of the system and are to be sustained; flow elements refer to the functions of the system and interact with the studied context. The main strength of MuSIASEM is found in its integrated nature. It also provides qualitative and quantitative information about the functioning of a system.

Some weaknesses are found as well. The social dimension is not fully addressed focusing on labor force and household consumption and there is no explicit incorporation of a participatory approach. Second, its descriptive nature makes it difficult to enhance sustainability related decision making and policy design processes. Third and last, it is found to be highly time consuming. It should be stated that these limitations have been partially addressed in a poverty analysis study case (Scheidel, Giampietro and Ramos-Martin, 2013) and more explicitly by Serrano-Tovar and Giampietro (Serrano-Tovar and Giampietro, 2014) where they propose a multiple source assessment in a rural environment, with a bottom-up approach gathering local data from farmers and a top-down using national statistics.

3.5. Discussion of the results

The previous analysis has shown that integrated assessment can contribute in different ways to sustainability and give different inputs that can be helpful for decision makers. In this section, results are observed in terms of how the selected methods enhance sustainability and decision making processes.

The selected methods were ranked following the sustainability weak or strong categories (see Table 3.1) that have been broadly implemented among consulted literature (O'Hara, 1995; Kant, 2003; Rescia *et al.*, 2008; Raymond *et al.*, 2009). Weak sustainability methods take into account terms and values that follow a standardized view of sustainability due to its translation into monetary terms (Naredo, 2001; Kant, 2003; Cabello *et al.*, 2014). Strong sustainability methods are those who adopt a broader scope that approaches to an interdisciplinary and systemic view of nature, society and also the economy (O'Hara, 1995; Gowdy, 1996; Rescia *et al.*, 2008; Raymond *et al.*, 2009).

Table 3. 1. Analysis of selected methods in terms of their contribution to consolidate sustainability.

Method	Main consulted authors	Approach / Case	Contribution to sustainability	Input for decision making processes
Life cycle methods	Jones, Rose and Tull 2011; Jørgensen, Herrman & Bjørn 2013; Klöpffer 1997; Shields et al. 2011	Environmental engineering & assessment; Policy making	Medium.- business oriented; main focus on the environmental dimension; lack of consensus regarding relation to sustainability.	Visualization of production-consumption model; internalization of associated costs; difficulty to communicate results.
Cost-benefit	Cordero et al. 2006; Falconí & Burbano, 2004; Munda, 1995; Runhaar, Dieperink & Driessen, 2006	Ecological Economics; Watershed case study	Weak.- centered on monetary values; commensurability issues.	Useful and clear results; better if complemented to broaden the scope.
Stakeholder analysis	Grimble & Wellard 1997; Rescia et al. 2008; Runhaar, Dieperink & Driessen, 2006	Socio-ecological system; Decision making; Rural landscape case study.	Strong.- captures traditional, cultural, economic and natural values.	Practical method; enables identification of solutions; offers a holistic view.
MuSIASEM	Giampietro, Mayumi & Ramos-Martin 2009; Madrid, Cabello & Giampietro 2013; Serrano-Tovar & Giampietro 2014	Socio-ecological system; Complexity; social metabolism.	Strong.- provides an integrated scope; includes quantitative and qualitative information; adaptive capacity.	Descriptive method; provides robust information; holistic view on how the system is functioning.

Table 3.1 classifies the four selected methods and main consulted authors, the kind of approach or application of the assessment, followed by the assessed grade of contribution to the consolidation of sustainability and the input for decision making processes that the instrument provides.

Life cycle methodologies are among the environmental engineering assessment instruments. They are considered to have a medium grade of contribution to sustainability due to their business orientation and focus on environmental impacts. Many other factors than the supply chain are involved (Jones, Rose and Tull, 2011), however this is partially addressed by LCSA. As for their input to decision making, these methods have relatively low incidence due to the difficulty in communicating their results. Even so, it is a recognized framework for studying the impacts of productive systems on the environment (Jones, Rose and Tull, 2011).

CBA is an economic instrument with an ecological economics approach. It is considered to have a weak contribution to sustainability mostly because of the implication of commensurability, implying that environmental or social services and goods can be substituted just like market ones. Notwithstanding its clear results when facing decision making processes, if benefits exceed costs, losses can be easily compensated by other means such as economic payments (Thampapillai and Thangavelu, 2004; Cordero *et al.*, 2006; López Paniagua *et al.*, 2007). CBA is still an important part of integrated assessment due to the ease of communication (everyone understands "money talk") and inputs for scenario building (Akhtar *et al.*, 2013). Researchers state that sustainability-related issues must be assessed by hybridizing different knowledge areas and values (Winslow *et al.*, 2011; Benessia *et al.*, 2012).

Stakeholder analysis accounts for the socio-ecological system approach and is strongly related to decision making processes. It has a strong contribution to the sustainability approach because it ponders diverse values such as traditional, cultural and natural ones. It also accounts for economic values, but enables the determination of common values and goals (Runhaar, Dieperink and Driessen, 2006; Mathur, Price and Austin, 2008). Social learning tools can be incorporated for more solid outcomes (Reed, 2008; van der Wal *et al.*, 2014).

MuSIASEM has a complex socio-ecological system approach. Its integrated scope provides a strong contribution to sustainability analysis. It includes both quantitative and qualitative data and its adaptive nature gives flexibility to the methodology which in turn suits the nature of sustainability (D'Alisa, Di Nola and Giampietro, 2012; Madrid, Cabello and Giampietro, 2013; Serrano-Tovar and Giampietro, 2014). As for the inputs for decision making, they seem more blurry due to its descriptive character and the much needed experts throughout the analysis. Nevertheless it is important to account that this analytic tool provides an almost exhaustive view of the way a system functions (Ramos-Martín *et al.*, 2009).

3.6. CONCLUSIONS

More than focusing on a general consensus as normally understood, what is here acknowledged is that efforts must be directed to broaden the scope under which sustainability is implemented. The idea is not to create a best-way to analyze and respond to sustainability related issues, but to build a diverse yet deep network that acts as a common base for further development.

Integrated assessment has been largely implemented as shown in the literature for analyzing sustainability. Each application has a specific knowledge background that determines the kind of approach and the degree of importance given to sustainability. They also generate different inputs for decision-making processes that can be more or less useful for enhancing these processes by communicating results and providing robust information for stakeholders.

Especially when related with complex issues that involve multiple scales and dimensions, integrated assessment is key to help decision makers find alternatives. In this sense, examples that are found to have a greater contribution to the sustainability approach provide a broader scope to analyze these alternatives in a systemic way so as to make better informed decisions. Although this can have an impact on the complexity of the decision making processes, it is worth the trade-off in order to be able to achieve more sustainable solutions.

The integration of the sustainability approach is still weak among the reviewed assessment tools. This is shown in the fact that environmental issues dominate over the more intangible social and institutional issues. Efforts are already being made towards this matter as shown by the social life cycle assessment, life cycle sustainability assessment and the execution of cost-benefit analysis as a complimentary device. However, stakeholder analysis and MuSIASEM are the examples that incorporate sustainability in a broader sense among the studied integrated assessment tools and if combined their performance could be even more useful for decision-makers.

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4 THE PRACTICE OF SUSTAINABILITY IN RESPONSE TO THE CHALLENGES OF AGRICULTURE IN MEXICO

ABSTRACT

In Mexico, as in most food producing countries, a complex problem is found in the convergence of a need for a change in the current agro-industrial model for economic, social and environmental reasons and growing food demand. While the existence of strong economic barriers that question the continuity of conventional agribusiness is recognized, it is observed that alternatives such as organic farming have emerged within the same productive and commercial model. Although a sustainability approach broadens the scope of analysis the question is if it consolidates better agricultural practices while supporting decision-making processes and achieving yield goals. Settling previous research results, this paper aims to answer this question through the transposition of theoretical aspects to a case study: a project currently being held in Jalisco, Mexico to promote organic agriculture among maize producers. The exercise provided useful information on results and drawbacks to be expected when applying sustainable principles on field. It was possible to implement practical actions appropriate to the socio-environmental context that matched economic goals of local farmers, improved soil quality and decreased environmental impacts and external dependence of rural Mexican communities. Never the less, the lack of trust between farmers and public institutions, skepticism towards change, prevalence of immediacy and uncertainty of resource allocation make it hard to achieve any progress questioning whether results can be maintained long-term to facilitate the transition of agroecosystems towards a more sustainable future.

Keywords: sustainability, agroecosystems, policy-making, organic agriculture, local development.

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4.1. Introduction

Described as the ability to meet present needs without compromising the ones of the future (WCDE, 1987), sustainability has become an important pillar when facing development issues. Therefore, searching for means to help the integration of sustainability into the processes that can lead real-world actions seems coherent. By this means, sustainable principles can become a common base to keep empowering actions towards more consistent decisions, policies and a more balanced development.

However, while its level of inclusion in discourse and theory is quite broad, sustainability as a discipline still needs to reinforce its operational side. There is a lack of consensus on the definition and practice of sustainability, which shows contradictions between its conceptual and normative conception. The latter refers to the interdisciplinary and diverse conceptualization of sustainability in contrast with its more reductionist predictive statistical practice (Benessia *et al.*, 2012).

The above has a dual effect: in one hand it gives a broader spectrum for sustainability to be applied on different fields and with a transdisciplinary scope (CEPAL-ESALC, 2004; Lang *et al.*, 2012); in the other, makes it harder to get solid results and therefore to be considered a scientific approach (Ekins et al. 2008; Hak et al. 2012). This is strongly related to the challenge of consolidating knowledge at the same time that decision making processes are enabled (Benessia *et al.*, 2012). Here is considered that contrasting the principles of sustainability with a case study is relevant to observe the consistency (or the lack of) between sustainability theory and practice.

In Mexico, as in most food producing countries, a complex problem is found in the need to change cropping practices for economic and social reasons and the consequent need for proposals to address the shortcomings of the current agro-industrial model (Aguilar-Jiménez et al. 2011). In this regard, on one hand the existence of strong economic barriers that question the continuity of the conventional agribusiness is recognized; and on the other, it is observed that alternatives such as organic farming have also emerged within the same productive and commercial model. Either way, the underlying problem is not being addressed. What is here required is a paradigm shift in agricultural production and marketing to one that allows a more equitable distribution of economic resources and a more sustainable use of natural ones.

The latter is embedded in a context that lacks the appropriate measures to boost local development in Mexico. Extra efforts to compel the creation of public spaces and policies are required. Then, through successful local experiences, dynamics can be generated to allocate resources to develop alternatives within a more holistic scope. This will in turn benefit both the environment and the social fabric at local and regional level (Astier et al. 2011; Aguilar-Jiménez et al. 2011; Koohafkan et al. 2012). The adoption of the principles of sustainability, agroecology and the common-good model in the food production and marketing processes is what will set the tone for a new agribusiness model with the well-being of the majority as priority rather than the economic benefit of the minority.

4.1.1. Aim and structure

This chapter focuses on analyzing the practical implementation of sustainability principles in promoting a transition towards a local organic agriculture to answer the challenges of agriculture in the Mexican context. After the introduction, section two focuses on describing the problem; a third section shows the methodology implemented in the project; the fourth section is dedicated to the achieved and expected results, and a final one deals with conclusions.

4.2. Agriculture context and challenges

Drastic land use changes have occurred in the past 40 years in grain producing countries such as Mexico, and have come with severe consequences being deforestation and land degradation for manure and grains of the most important (Ding *et al.*, 2013; Huerta *et al.*, 2014). Even though every single modification of the natural environment means losing its original characteristics, it has been the adoption of a monoculture agribusiness model what has caused the rapid devastation of agroecosystems in the country (Picture 4.1). This has caused a deep impact in society (rising poverty, concentration of resources and means of production, rural exodus, etc.) and in the environment (soil degradation, water sources pollution, biodiversity losses, increased vulnerability of ecosystems, etc.).

FIGURE 4. 1. MAIZE MONOCULTURE JALISCO, MEXICO. EVERY SIGN SHOWS CHEMICAL INPUTS AND / OR MODIFIED SEEDS USED IN THE FIELD. PREPARED BY THE AUTHOR.

The so-called "green revolution" of the 70s – though its roots can be traced back to 1943 – was carried with the aim of increasing field production through the search of high yielding varieties (HYV) and intensive agriculture (Castañeda Zavala *et al.*, 2014). However, as pointed out by different researchers, it has resulted in effects such as the loss of genetic biodiversity, soil impoverishment, increased agrochemical pollution, health issues among rural population on the rise, among others (Huerta *et al.*, 2014). Figure 4.1 sets an example.

Paradoxically the productivity of this whole system is questioned when considering its high dependence on external technologies, the cost of inputs and its negative effects on human health and the environment (Altieri & Toledo 2011; Koohafkan et al. 2012; Astier et al. 2011). Due to the implementation of this massive food production system agroindustry is now consolidated worldwide prioritizing markets, technologies and knowledge at global scale over local ones.

4.2.1. Maize

In the world, the production of maize has been increased in more than 100% over the last 20 years. In 2013 1.018 million tons were produced globally, more than doubling the 467 million tons produced in 1993. It is the third most produced crop in the world, and 50% of it is produced in the American Continent (FAO, 2014).

Maize gains even more importance in Mexico, where it is the most important crop both in volume as in planted area (CEDRSSA, 2014). Regarding maize, Mexico is fourth in production, fifth in seed production and second in imports with more than 10 million tons per year, placing the country as one of the main consumers of this grain (FAO, 2016). It is worth mentioning that Mexico is self-sufficient on white maize destined mainly to human consumption, but highly deficient in yellow maize destined to industrial uses and feeding cattle, importing 90% of its final consumption (CEDRSSA, 2014).

Maize is the basic grain of the national diet and a cornerstone in the cultural identity of the Mexican people in general and of indigenous people in particular (Aguilar-Jiménez et al. 2011; Carro-Ripalda & Astier 2014; Altieri & Toledo 2011). Mexico counts with 64 different varieties of maize, it is recognized as the country with more genetic diversity and therefore, as the cradle of this grain (Arnés *et al.*, 2013; CONABIO, 2015).

Taking this into account is quite clear that consequences of implementing monoculture production of maize are more evident in Mexico, where biological diversity and intangible heritage are to be maintained. Hence, incorporating more sustainable practices in agriculture by adapting methods to the local context, recovering traditional practices and developing techniques according to the social and natural environment is suitable and much needed. The latter is more relevant considering the great difficulties of making compatible the feeding needs of a growing population with the urgency of mitigating impacts to the environment, where the adapting capacity must be strengthened within a context of socioeconomic crisis and climate change (Koohafkan et al. 2012; Bender & van der Heijden 2015; Verhulst et al. 2010; Huerta et al. 2014; Altieri & Nicholls 2012; Calleros-Islas & Welsh-Rodriguez 2015).

4.2.2. ORGANIC FARMING

Defined as a production system based on maximizing the use of natural resources that are present in crop lands, organic agriculture goes beyond prohibiting agrochemicals. It seeks to maintain (and even enhance) fertility and biological activities of the soil without using synthetic inputs and, whilst minimizing the use of non-renewable resources. All is meant to reduce the impact of agricultural activities on both the natural environment and human health (Andersen, 2003).

Agricultural organic land has been constantly rising worldwide since several decades going from 11 million hectares in 1999 to 43,1 in 2013. The organic food market has also grown, especially since 2002 and unlike the rest of the food market, has continued to grow regardless the global economic downturn (Willer and Lernoud, 2014).

While consumption and market of organic products is largely concentrated in the countries of the global north (mainly U.S.A. and E.U.) developing countries concentrate 80% of all organic producers. Latin America is first in total organic agricultural land with 6,6 million ha. But if considered as the share of total agricultural land, this changes. For example, Argentina is number one in area with 3,2 Mha and Mexico ranks sixth with only 0,5 Mha. As a share of total agricultural land Argentina goes to the ninth place with 2,3% and Mexico to number seven with the same percentage (Willer and Lernoud, 2015). As observed, this consideration almost erases the difference between the two countries, but what these data are revealing is how little relevance organic farming still has in Latin American countries.

THE MEXICAN CONTEXT

Mexico has 501.364 ha (2013 data) of organic agricultural land, reaching the 2.27% of the total agricultural land. After Greece, it is the second country with the highest annual increase reaching a 32.8% growth from 2011 to 2012 (366.904 ha in 2011). In the 2012-2013 period, this decreased to a 2,9% corresponding to one of the flash points of the world economic crisis. Mexico is also the country with the largest number of organic producers in Latin America (169.000 in 2013) and third worldwide (Willer and Lernoud, 2014, 2015).

The main organic produced crop is coffee, as befits one of the leading countries in producing and exporting organic coffee, representing 35% of the total organic production. In relation to other countries

Mexico has a diverse production highlighting avocado, citrus, honey, tropical fruits and vegetables in general (Organic Trade Association, 2015).

Even so, as in most food producing countries, organic agriculture in Mexico has been oriented to export benefitting large scale producers. From the total organic production of the country 85% is exported, mainly to the United States (Organic Trade Association, 2015).

The use and production of organic inputs are a viable option for increasing the profitability of crops, especially considering that market prices are higher than those of conventional products. However, this applies only to products certified as organic and this process involves high costs in time and money (Astier et al. 2011; Koohafkan et al. 2012). Also to be noted, changing the productive system is not something farmers can do overnight. It is a process of transition that involves many boundaries to overcome.

The farmers perspective

One of the biggest challenges for small and medium farmers in Mexico is the rising prices of conventional inputs exacerbated by the financial market situation. Most of them (80%) being imported goods and with the peso devaluation, conventional inputs are more expensive with an increase from 30 to 50% (Valdez *et al.*, 2015). The decreasing effectiveness of these inputs is added creating a loop effect when applied periodically, generating negative effects on human and environmental health.

Today, farmers are firsthand watching how the effects of continued use of such inputs are seriously increasing. In addition, commercializing companies operate under a market-oriented logic that often goes against the interests of local producers (Govaerts *et al.*, 2009; Altieri and Toledo, 2011; Carro-Ripalda and Astier, 2014).

Some common opinions of Mexican maize farmers (with less than 20 ha) include that though organic farming is a trend for the future and only for exported high profitable crops. Current organic certification mechanism is foreign to them. They are also no longer searching for higher yields but for higher profitability, applying new inputs only if they are well-warranted and/or involve lower costs. They express a need for more economic incentives and subsidies especially because of the market volatility but also because of skepticism towards change. There is also a lack of trust towards public institutions and local farmer organizations because of corruption cases occurred in the near past (Campo Orgánico Empresarial, no date).

Therefore, organic farming must go beyond simply replacing supplies if the target is to involve medium and small farmers. Aspects such as the dependence on the exterior, agriculture based on monocultures, impositions of foreign markets (such as certificates) and other issues as water stress, should be considered. Otherwise, the progress of local agro-ecosystems in terms of sustainability and resilience will be quite limited as seen in Baja California, Mexico, where organic farms have been increasing, overexploiting aquifers and seriously compromising the water sustainability of the region (Rosenthal, 2011).

This is primarily due to conventional agribusiness itself that for merely economic reasons, have promoted the use of organic inputs under the same standards of transnational corporations (Altieri and Toledo, 2011; Koohafkan, Altieri and Gimenez, 2012). Even Monsanto (2015) declares in its web page that counts with "conservation agriculture" products and methods, promoting low hazard herbicides that respect the environmental biodiversity.

The latter is embedded in an institutional context that has not been able to fully cover what rural communities truly request. An inclusive approach to address socioeconomic and environmental challenges faced by local producers is still missing (Reed, 2008; Astier *et al.*, 2011; Rogé *et al.*, 2014). This implies creating spaces for designing public policies that do address the shortcomings of the agribusiness model that still prevails in development plans at national and state level in Mexico, which are permeated by the private interests and neoliberal principles that have guided the government's actions over the last 30 years (Holt-Giménez and Altieri, 2012; Merlín-Uribe *et al.*, 2013; Carro-Ripalda and Astier, 2014).

4.3. Methods

The project "Organic farming promotion and development for grain producers in the state of Jalisco", object of the present research, focuses on enhancing the transition towards organic production of basic crops to the Mexican diet in Jalisco, Mexico. The work is mainly with 3 groups of maize farmers being 40 participants in total and the project is planned to last 4 years.

The focus is placed in organizations of medium-scale producers (between 5 and 20 ha). This is because these producers have resources of their own and interest because they are personally involved in their crop lands. Medium-scale producers also have an important function on shaking the dynamic of other farmers in the region and since the project has a clear interest in reconstructing the social fabric of rural communities, has placed among them its core activities.

As a transition process, the first goal is to reduce production costs. Therefore, even though the price of commercialized products will remain the same, the direct cost-benefit relation will be more favorable for the farmers. Other important benefits will be obtained such as improving the soil quality, reducing environmental impacts and diminishing dependence with the exterior (Govaerts *et al.*, 2009; Arnés *et al.*, 2013; Ding *et al.*, 2013). These factors will considerably improve the agricultural land conditions that future generations will inherit.

4.3.1. Study area

Being recognized as the place of origin of maize, it is assumed as a well-adapted crop to the Mexican climatic and natural environment (Arnés *et al.*, 2013). In concrete, Jalisco has the physical characteristics needed to develop diverse cropping activities. Specifically, maize finds in this territory a favorable environment for its development reason why it is the most important crop in the state (Castañeda Zavala *et al.*, 2014).

Jalisco is located in western Mexico (Figure 4.1) and bordered by 7 other states and by the Pacific Ocean to the west. It has an area of 80.137 square kilometers and 68% of the territory has temperate humid weather with summer rains. The average annual temperature is 20.5°C and has 850 mm average annual total precipitation.

FIGURE 4. 2 MAP OF THE LOCATION OF JALISCO IN MEXICO. ADAPTED FROM GOOGLE MAPS (2015).

Jalisco is settled in an area where different weathers converge because its territory includes tropical and subtropical regions appropriate of the southern hemisphere as well as temperate and cold regions of the northern hemisphere. Also, three of the four most important mountains of the country come together in Jalisco: Sierra Madre Occidental, Eje Neovolcánico Transversal and Sierra Madre del Sur, in addition to valleys and 351 km of coastline. This endows great ecological diversity highlighting biodiversity, ranking sixth at national level. Maximum altitude is 4260 meters and the lowest is at sea level. Several bodies of water are found too accounting for 15% of Mexico's inland waters, like the Lerma-Santiago River and its tributaries, the Chapala Lake and the Peña Cajon dam (CONABIO, 2015).

Jalisco is second only to the state of Sinaloa in maize production in the country (SAGARPA, 2015). However, ranks first in rain-fed crops thanks to precipitation and weather which endows greater sustainability for not depending on expensive irrigation systems or external sources of water.

The project started on July 2014 and was launched aiming to promote directly with farmers a process of transformation from an agrochemical based agriculture to an organic one at local level framed in the principles of agroecology (Koohafkan, Altieri and Gimenez, 2012; Altieri and Nicholls, 2013). Participant producers belong to the following organizations (Figure 4.3):

- The Ejido Union Exlaguna de Magdalena in the municipality of Etzatlán.
- The society of rural production (SPR for its Spanish acronym) “Hacienda Los Godinez” in the municipalities of La Barca and Jamay.
- Two groups of the Teocuitatlán de Corona municipality.

FIGURE 4. 3 MAP OF THE PARTICIPATING ORGANIZATIONS IN JALISCO. ADAPTED FROM CONABIO 2015.

4.3.2. Diagnosis

At first, not so favorable comments arise between small and medium farmers when considering organic agriculture as an answer to the problems they face. This is because the closest references lead immediately to elitist markets that impose different requirements involving costly investments and complicated procedures that are beyond the reach of most producers who operate at small and medium scale (Astier *et al.*, 2011; Koohafkan, Altieri and Gimenez, 2012).

But today organic farming must be placed far from a fad among elite producers and consumers around the world to be identified as a necessity for the people (Campo Orgánico Empresarial, no date). Proof is found in producers themselves pointing out the need to change as they directly observe the negative effects of the continued agrochemical application in soil quality and health of the population.

Therefore, one of the goals is solving this problem by providing producers with the basic technical elements enabling them to develop their own organic inputs with local resources. This is an important part of the basic principles of agroecology (Altieri and Toledo, 2011; Holt-Giménez and Altieri, 2012). By doing so, an immediate double effect is generated: in one hand, environmental pollution levels and the exposure of workers to chemicals will considerably decrease; in the other, community resilience is increased and the capacities of the local population are strengthened, decreasing its external dependence (Koohafkan, Altieri and Gimenez, 2012; Arnés *et al.*, 2013; Huerta *et al.*, 2014).

4.3.3. General objective

Participating groups and the project development consultancy Campo Orgánico Empresarial (Organic Rural Businesses), with the financial support of the Ministry of Rural Development of Jalisco (SEDER, Spanish acronym) joined forces to enhance transition towards organic farming.

The proposal was made and entirely driven by Campo Orgánico Empresarial. It was filed to the SEDER searching for financial support because "it is responsible for promoting the agricultural, fishery, aquaculture and agro-industrial development; as well as the integrated and sustainable rural development of the State of Jalisco" (SEDER, 2015).

In broad sense, it is meant to produce food free from synthetic inputs and/or chemicals that can be harmful to the health of the population in general and in particular for direct workers (Ichikawa, 2015). This would create positive influences for local consumers to easily access a healthier diet. The environment in the region would be favored with reduced agriculture impacts, improved water quality and increased soil microbiota and minerals. The latter is of major importance for the serious problems of soil nitrification and filtration of chemicals to aquifers in the region due to cropping activities (Ding *et al.*, 2013; Bender and van der Heijden, 2015).

4.3.4. Specific objectives

The project is carried out through four strategic lines that shape the action plan (Figure 4.4): a participatory diagnosis, advisory sessions, training sessions and a final participatory evaluation. The first two steps have already been done with training sessions currently taking place while participatory evaluation is yet to be done.

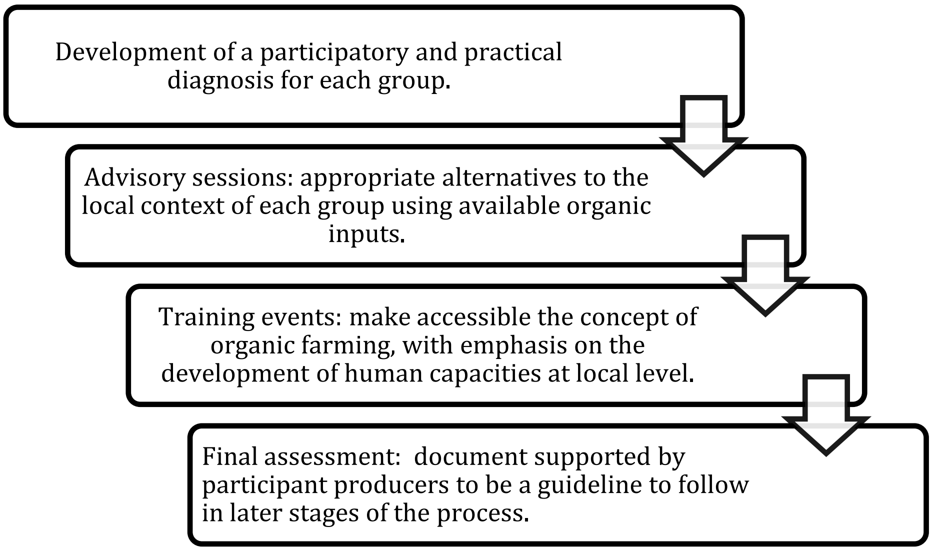

FIGURE 4. 4 STRATEGIC LINES OF THE PROJECT. BASED IN DOCUMENTS PROVIDED BY CAMPO ORGÁNICO EMPRESARIAL.

Through the participatory diagnosis, firsthand information on the current situation is collected. Capacities and projection of each group are identified as well as the profile of leaders in the group, the opinion of farmers on changing cropping methods, directors-producers-technicians relationships, productive and technological issues, and existing local expertise on organic farming transition to adapt following activities to each context.

In the advisory sessions, most appropriate alternatives for each group are displayed, using organic ingredients available on the market and produced by national companies. Costs are reduced and production processes become more efficient, but the final goal is that farmers take ownership of their management and application.

Training sessions are meant to make accessible the concept of organic farming for rural population, emphasizing the importance of locally developing human capabilities. Input production will begin in these events under the "learning by doing" method, which strengthens social participation and rebuilds social capital.

Final evaluation consists on a document endorsed by participant producers to be a guideline for future stages of the process. The goal is to allow adapting the action plan for dissemination.

4.4. RESULTS AND DISCUSSION

Each producer personally determined the surface allocated to transition towards organic farming. Organic inputs were tested according to proportions in Table 4.1.

TABLE 4. 1. DISTRIBUTION OPTIONS OF THE TOTAL CROP LAND BETWEEN CONVENTIONAL AND ORGANIC SYSTEMS.

	Percentage of Has engaged in conventional farming	Percentage of Has engaged in organic farming transition
Option 1	70%	30%
Option 2	60%	40%
Option 3	30%	70%

4.4.1. ACHIEVED RESULTS

Actions developed in the area destined to organic farming transition (Figure 4.2), regardless the percentage of total area that represents, started with a process of soil recovery. This included fertilizing with humified and mineralized organic matter and reducing by half chemical fertilization. Then, bio-enzymes were applied in the leaves of plants to nourish them and fight some pests, especially in early development stages. Finally, a custom non-chemical control of pests and diseases was established to match the characteristics of each agricultural ecosystem.

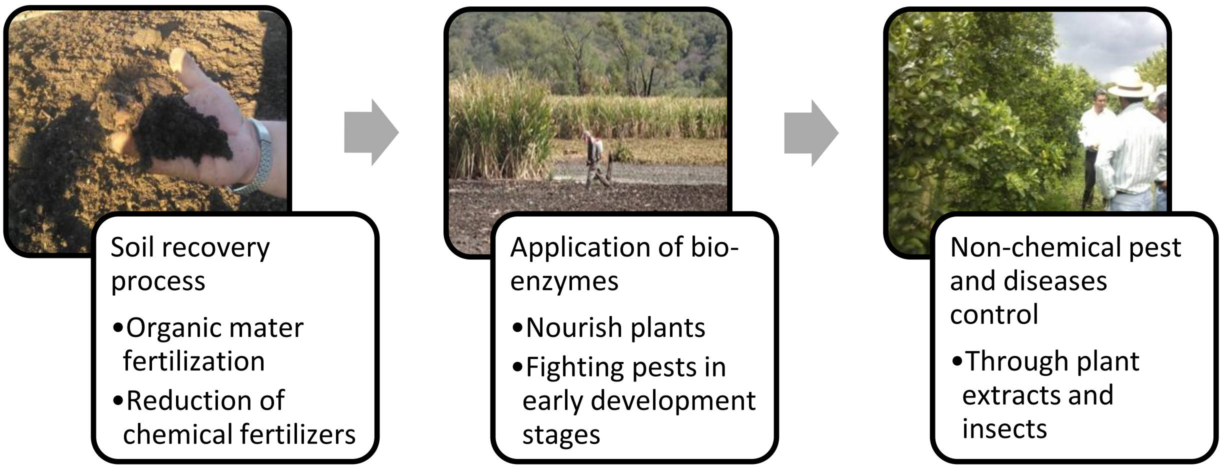

FIGURE 4. 5 ACTIONS DEVELOPED IN THE AREA DESTINED TO ORGANIC FARMING.

After two years, the main results are the reduction of total costs in 20% and the elimination of half the chemical inputs applied. Of especial importance is the abandonment of broad-spectrum non-selective herbicides and insecticides. The use of urea was substituted with organic inputs in 50% in comparison with conventional cropping system which is translated in cutting by half the risk of eutrophication and other impacts such as ammonia and nitrous oxide emissions (FAO, 2016). Soils have been enriched considerably with organic matter and minerals decreasing compaction, salinity and acidity. These results were observed on-site through simple empirical tests and monitoring. For example, soil compaction was hand measured to check its porosity in each period, before and after incorporating organic matter.

4.4.2. Expected results

Having provided the necessary technical elements to the groups, in the medium term it is intended to build production systems of organic inputs or "bio-factories". These systems enable producers to locally develop the organic inputs needed for each crop using their own natural and economic resources. For implementation, strong advising and training actions of organizations are needed as well as sharing of farmer-to-farmer experiences.

Economic viability may be simply verified considering that installing a bio-factory with 500ha supplying capacity (considering operating expenses and costs in Mexico) profits are obtained in one year. Just chemical fertilization requirements for the same 500ha amount to more than 100.000€ (SAGARPA, 2015), and being substituted with organic inputs from the bio-factory it is clear that the project brings significant economic benefits for local producers.

The production of solid and liquid organic fertilizers, green manure from native plants, mineral and manure bio-enzymes, as well as bio-control of pests and diseases, are the main functions of the bio-factories. They also help restore the balance of minerals and organic matter of soils and allow the use of raw materials from crop residues and underused local resources, such as manure, minerals, herbs and / or natural repellents (garlic, onion, chili, etc.) with the consequent reduction of costs (Govaerts *et al.*, 2009; Fuentes *et al.*, 2011; Ding *et al.*, 2013; Bender and van der Heijden, 2015). In addition, control of production processes is given to local producers creating employment in the communities, increasing their self-sufficiency and their ability to adapt to changes (Koohafkan, Altieri and Gimenez, 2012; Arnés *et al.*, 2013). Autonomy of rural communities will increase by generating added value in the region.

Actions are expected to be carried out by each group through inclusive practices and participatory processes to upgrade rural areas through strengthening family bonds (Campo Orgánico Empresarial, no date). This will be achieved through diversifying productive activities at local level and developing rural social enterprises (cooperatives), helping slow down migration and field abandonment processes that favor family disintegration and impoverishment of rural societies in Mexico.

Local production of organic inputs through a gradual process based on the availability of natural and economic resources will be complemented with the remaining 40% of inputs that cannot be produced locally for high technical and infrastructure requirements, such as the reproduction of fungi, bacteria and other beneficial organisms.

4.4.3. Discussion

Limited economic resources prevented us from carrying out chemical analysis of soils. This hampered the possibility of monitoring chemical composition and therefore more solid results were not achieved. Instead, empirical tests based in direct observation and unstructured interviews with farmers were made and contrasted throughout the process.

The most important drawback was the mismatch between public administration deadlines and crop stages that rely on seasonal changes, especially when it comes to rainfed crops. This translated into significant delays and hindered the development of the action plan. Also, generated a negative effect on the farmers as highlighted by technical staff from Campo Orgánico Empresarial, because uncertainty setbacks their involvement in the project and prevented them from completely leaving the use of chemical inputs. Instead of this, they mixed organic and chemical ones, mainly because they expect more guaranties on the outcomes, and are skeptic towards drastic changes, especially on plague control issues.

However, achieved results imply that if the project carries on with special emphasis on training and caring more for accompanying the producer along the crop stages, success of the project can be expected.

4.5. Conclusions

Providing profitable alternative for maize farmers is mandatory against the rural backdrop in Mexico. Being maize the main crop in Mexico and Jalisco the largest producer of rain fed maize in the country the project "Organic farming promotion and development for grain producers in the state of Jalisco" is considered a key action for achieving rural sustainability at regional and national scale.

In this first stage, research focused on describing and evaluating achieved and expected results by contrasting them with agroecology and sustainability guidelines. I considered that the more included these principles are, the more likely to it is to achieve success for sustainability related actions.

This paper made clear that positive outcomes can be expected from applying sustainability principles and that these are not limited to improving the environment, but that actual economic and social benefits are possible. Emphasizing on local communities, their ability to experiment, implement and evaluate innovations in agricultural production systems increases the width of positive outcomes from public investment in agriculture. Crop management technologies and methods that can be locally applied while promoting natural diversity and social integration, underline that if searching to generate more opportunities for rural population, any action in this area should take into account the development of social capital and the principles of agroecology. The importance of this fact is highlighted in the current scenario that prevails in the country where the complex social, economic and political problems that have occurred (especially) over the past 15 years, have equally damaged the social fabric, the function of public institutions and the environment.

Research as well as the project, were limited by time and economic resources so carrying chemical soil analysis was not possible. The latter impeded getting tangible data on how actions made really impacted the soils composition and biological activities. If future research allows this, it will enable to deepen the analysis and to assess its effects even at early stages.

Some setbacks were also identified. The immediacy of agricultural seasons and cropping stages including natural conditions prevents farmers from waiting public administration deadlines and periods. This means that farmers cannot wait for programs to be accepted and resources to be liberated to continue their activities and much needed technical advice arrives late, having to adapt original actions to what farmers already made. This was identified as the main reason why farmers did not leave their transition cropland area totally free from chemical inputs. Also, mistrust between farmers and public administration, but even among themselves is an important obstacle to overcome though some progress was achieved by working in groups and through participative approaches.

Further research is needed in order to assess how the project actually impacts the compound between local society and the environment. This can be done through implementing and evaluating three fundamental aspects: a tool of analysis composed by theoretical principles and integrated assessment of sustainability; how the implementation of this tool contributes to strengthening the operational capacity of the sustainable approach and if enhances decision-making; and finally the extent to which the project achieved its objectives in terms of grounding sustainability and locally strengthening natural and social capital.

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5 SUSTAINABILITY ASSESSMENT. AN ADAPTIVE LOW-INPUT TOOL APPLIED TO THE MANAGEMENT OF AGROECOSYSTEMS IN MEXICO

ABSTRACT

Agriculture is a key sector in going towards sustainability. It works as a hub between social, institutional, economic and environmental dimensions. An international recognition has risen on how efforts must be directed to sustainable agriculture if current challenges of soil degradation, climate change and population growth are to be overcome. This is translated in the need for means to assess and evaluate progress (or the lack of) towards sustainable agriculture. Although literature on assessment methods for the matter is abundant, a research gap is found on tools suitable to the local context in developing countries like Mexico, where data and skills availability greatly contrast between regions and municipalities. Aiming to bridge this gap, the Sustainability assessment Adaptive and Low-input Tool (SALT) is presented. Conducted analysis focused on contrasting two crop management systems in western Mexico: conventional, the most common in the region; and alternative, relative to farmers transitioning towards sustainable agriculture. A four-step process was followed: 1) substitute indicators were derived on field through participatory workshops, interviews and field trips; 2) analyzing the impact of maize management systems in the region and determining factors that can trigger tangible changes on the behavior of the system; 3) integrating this analysis and a sustainability framework to build up the SALT; 4) application of the tool and interpretation of the results. Sustainability is constantly evolving as an approach, but must keep strengthening practical aspects. Therefore, assessment tools should be tailored to allow an adaptive application and interpretation.

Keywords: sustainability; sustainable agriculture; agroecosystems; local level; assessment tool.

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5.1. Introduction

Broadly speaking, sustainability is being concerned about the effects that present actions may have on future generations (WCDE, 1987). The concept has gained weight over time, especially in the last 20 years being widely included in research across fields, private sector and public agendas at global, national and regional scales (Meadows, 1998; Scialabba, 2000; Clark and Dickson, 2003; Shields, Blengini and Solar, 2011).

United Nations embraced the sustainable approach as an important pillar of its discourse since 1992 at the Earth Summit in Rio de Janeiro becoming at the same time its main endorser at international level (United Nations, 1992). For example, Millennium Development Goals turned into Sustainable Development Goals (SDGs) broadening the scope and becoming a more integrated transformative global agenda (United Nations, 2015) but also challenging and complex (Munasinghe, 2012; Allen, Metternicht and Wiedmann, 2016; Hák, Janoušková and Moldan, 2016). Considering that former agendas had economic growth as cornerstone (Kosoy *et al.*, 2012; Bowerman, 2014; Sahakian, 2014; Giannetti *et al.*, 2015) sustainability being able to stay in national and international agendas, even if just discursively speaking, is an important step.

Agriculture plays a significant role in the SDGs agenda. It is recognized that the key to achieve the whole set of 17 goals comprised by 169 targets is food and agriculture. Therefore goal number 2, achieving food security through the promotion of sustainable agriculture, is a 'hub goal' (FAO 2016). Therefore, specific attention should be paid in designing strategies for its fulfillment.

Without getting into the debate on how adequate or realistic the SDGs are, the challenge for all, the world, nations and civil society, to feed a rising population while maintaining life systems with limited resources is remarkable. And the way to find answers to this challenge is through sustainable agriculture (Kanter et al. 2016). Though it may seem trivial, it is worth to highlight that to fulfill one of our most basic needs – being fed – we have heavily impacted the natural environment, so we must move towards sustainable methods. This implies that technology on its own "will not do the trick", which is important given the weight the technological fix had in the discussion over the years (Räikkönen 2014; Struik et al. 2014; Holt-Giménez & Altieri 2012; Levidow & Paul 2010).

The objective of my research is then to design and implement a tool to enable an integrated assessment of sustainability in local contexts characterized – more noticeably in developing countries – by limited human, economic and time resources. It is important to note that with many assessment tools available (Shields et al. 2011; Runhaar et al. 2006; Binder et al. 2010; Cinelli et al. 2014) the Sustainability assessment Adaptive and Low-input Tool (SALT) here presented is meant to cover a gap found in literature on adaptive and low-input assessment methods for the local context. It integrates a sustainability framework and elements from a methodology that has been successfully applied in different contexts: the methodology for evaluating natural resource management systems incorporating indicators of sustainability (MESMIS for its Spanish acronym) (López-Ridaura et al. 2002).

The idea I will stress here is that finding strategies towards sustainable agriculture is mandatory, not only to farmers and related professionals but to anyone involved in the food supply-consumption chain. This paper aims to present the results of actions that enhance sustainable agriculture through applying an integrated assessment tool adapted to the local context in a case study. The target is not to actually measure and monitor commonly used sustainability indicators at field level but to contribute strengthening the practical aspect of sustainability and to identify guidelines to assess the effects of these actions within a low-input framework.

This chapter is structured as follows. A first section describes the context. Section two presents the SALT methodology based on incorporating a sustainability framework and flexible indicators to be applied at local scale on a case study. Section three explains the theoretical framework. On a fourth section, results are presented followed by discussion and concluding remarks.

5.2. Context

Agriculture is currently the sector that provides work for 40% of the world's population but only represents 3.9% of the world's gross domestic product (GDP) while industry and services a 29% and a 68% respectively. This manifests the breach between agriculture and welfare linking the sector to poverty: globally speaking peasant farmers produce 70% of the food supply (FAO 2016; WB 2016). In turn, agriculture is the productive activity that impacts most the social and natural environment (Reeves et al. 2016; United Nations 2015). The resources needed for agriculture are estimated in one third of land surface and three quarters of available freshwater (Kanter et al. 2016). Moreover, agriculture highly contributes to climate change, but is also highly vulnerable to its effects (Holman et al. 2017; Vermeulen et al. 2012).

The latter gains weight regarding population growth scenarios that set it at 9.2 billion in 2050 with the consequent rise in food demand (Hecht et al. 2014; Srivastava et al. 2016) and the urgent call to strengthen sustainability and resilience of agroecosystems (Srivastava et al. 2016; Astier et al. 2011; Altieri et al. 2015). Before the latter, intensification seems unquestionable but is far from being 'the' answer. Then, seeking alternatives must follow a sustainable approach that allows consensus, adaptability and 'out of the box' thinking (Struik et al. 2014).

In the Mexican context, same global trend is observed with a 3.6% of the GDP from agriculture (industry 23%; services 63%). The sector has a share of 13% total labor force (WB 2016). Agriculture activities gain weight when considering social and cultural aspects that are bonded to the sector, especially in the case of maize that has been cropped in the region for thousands of years. In 2012, one out of three cultivated hectares was dedicated to maize (SAGARPA 2015). Despite the existence of sustainable traditions on cropping and consumption of maize, socioeconomic tendencies both inside and outside the country have led to the prevalence of conventional management of agriculture (Altieri & Nicholls 2013; González-Esquivel et al. 2015).

Another factor that has heavily influenced food production systems in Mexico is related to changes of agrarian policies. Particularly, trade liberalization and market preferences towards yellow maize cropping for industrial uses have stimulated major land use changes with irreversible impacts in the region (Astier et al. 2014; Altieri et al. 2015). As a result, the way agroecosystems are managed is subdued to the technologies and practices promoted by existing programs and credits (González-Esquivel et al. 2015). Example of this is the production of yellow maize for the industry that is replacing white maize – a food crop basic for the Mexican diet (Castañeda Zavala et al. 2014).

5.3. Materials and methods

Following the stated by González-Esquivel et al. (2015), a framework that links sustainability assessment with the maintenance of ecosystem services while accounting for trade-offs must be the basis to analyze and forecast the state and role of agroecosystems to identify drivers and trends. The MESMIS is a tool in concordance with these statements. The tool is rooted in a systemic definition of sustainability and led by the principles of agroecology (Astier et al. 2012; Altieri et al. 2015). The method consists of four basic steps: (i) defining the socio-environmental context; (ii) a detailed characterization of the environmental, economic and social dimensions; (iii) identifying the factors that limit the capacities; and (iv), developing, measuring and monitoring of indicators selected as pertinent for the evaluated system. The MESMIS methodology incorporates cost-benefit and stakeholders analysis. It does not however, fully conduct them.

Although MESMIS has a solid theoretical base and presents a framework to evaluate the sustainability of natural resource management systems, it has some weaknesses regarding the locally-driven analysis here proposed. First, the methodology does not assess the institutional dimension which is considered of great significance in local agricultural contexts in developing countries like Mexico mainly for the dependence on subsidies of the sector (Munasinghe 1993; Srivastava et al. 2016; Dougill et al. 2016).

This limits the influence of the tool in decision making processes and the design adequate policies generally recognized as poor in such contexts (United Nations 2015), where there is a mismatch between national policies and the dynamics observed in rural localities (Balme & Ye 2014; Scialabba 2000; Constantin et al. 2015; Gault & Gonzalez 2009). Regarding the established criteria to evaluate sustainability of agroecosystems, there is no reference to sustainability as a whole showing a lack of a holistic approach that limits the perspective of obtained results (Fenech et al. 2003; Naredo 2001) based in managing natural resources in a sustainable way (Arnés et al. 2013; López-Ridaura et al. 2002). The scope should be more integrated in order to state that the system as a whole is being evaluated and not just the sum of the parts (Gallopín 2010; Novo 2006).

Also, though the tool is implemented at local level and can be downscaled to farm level, the indicators typically selected for the assessment are not easy to measure if the process is not driven by experts. Evaluation teams of 9-20 individuals and over two years are needed to implement the MESMIS as reported in literature (López-Ridaura et al. 2002). This is a tough task when resources are limited and data is not available which would compromise the obtained results. This is considered as inconsistent with a local assessment approach that should be tailored to local characteristics which not always include a team of experts with resources to make, for example, chemical soil and water analysis (Banco Mundial et al. 2001). An example of downscaling issues can be observed in the Millennium Development Goals at state level in Mexico where several bias in time-series hinder the evaluation of the indicators performance (INEGI 2017).

The SALT is developed as an attempt to answer these limitations towards the need to incorporate a broader characterization of the four dimensions of sustainability within an assessment tool. It is designed specifically to be applied and conducted at local level. The novel approach in SALT is that from the start allows the substitution of indicators and the use of locally available information in exchange of the hard to find data needed for applying large-scale frameworks that are driven by experts. It is a locally-driven methodology with a global perspective in response to the present international agenda that recognizes that world-wide issues must be answered at local level especially regarding agricultural systems (United Nations 2015).

The latter is proposed in agreement with the aim for making more operative the sustainability principles (O'Hara 1995; Burford et al. 2013; Spangenberg 2014) which is specially needed in developing countries where resources are limited and socioeconomic and environmental concerns increase (Goergens & Kusek 2010; Pant 2015; Schut et al. 2016).

5.3.1. CASE STUDY

Jalisco is a Mexican western state (20º34′00′′ N and 103º40′35′′ W) with an extension of 80,137 square kilometers. The weather is mainly temperate humid with 20.5°C average temperature and 850 mm total annual precipitation. Agriculture is an important activity in the state, being the main contributor to the primary sector in the country with a share of 11%. In maize, is second in total production and first in rain-fed maize with over 3 million tons and 605 thousand hectares (Secretaría de Desarrollo Rural 2014).

A trend is observed in the region on abandoning the full application of the "technological package" advised by supplier companies and well-learned by farmers. This consists on using the inputs required for the whole cropping process from preparing the soil and weed removal to attending specific plagues and diseases. Some of these inputs are being replaced with more natural ones mainly for economic reasons, but there are farmers sensitized by health and environmental issues (conducted interviews).

The selected case study is the project "Organic farming promotion and development for grain producers in the state of Jalisco" (Calleros-Islas 2017). It focuses on the management of agroecosystems (mainly maize) in the agricultural valley of the state focusing on the municipalities of Etzatlán (20°46′00″N, 104°05′00″W), La Barca (20°17′00″ N, 102°34′00″ W) and Teocuitatlán de Corona (20°01′00″ N, 103°11′00″ W). The studied area is mainly characterized by volcanic derived sandy loam and sandy clay loam soils with acidic to neutral pH (4-7) and a range of organic matter that goes from <1 to 3% of the soils composition (SEDER 2015; Mohamed et al. 2014). The project was planned as a four-year project but for several setbacks lasted two years instead and even then, interesting short-term trends can be observed. The aim was to enhance the observed trend towards a more sustainable local agriculture of basic food crops through a participative approach as an alternative to expensive organic certifications for export crops (McGee & Alvarez 2016; Delmotte et al. 2016). Having resources and interest from the start, organized medium-scale maize producers (between 5 and 20 ha) were targeted. In total, 40 farmers participated from three different organizations. The first objective was to reduce production costs making direct benefit-cost ratio more favorable. Also, the improvement of soil quality, the reduction of environmental impacts and increasing resilience were aimed. From 40 participant farmers, 28 actively engaged in the monthly participatory workshops that consisted on raising awareness, empowering farmers, training and developing a tailored transition plan. The rest only assisted and incorporated some of the organic inputs provided.

A comparison was made between conventional and alternative maize management systems to assess their performance and observe tangible results of implementing a transition to sustainable local agriculture after two years of activities. Conventional agriculture is here understood as the prevailing cropping system that is intensive in capital and synthetic inputs at large scale (Huerta et al. 2014). In the analysis here presented, the conventional system was characterized through a representative sample of medium-sized cropping systems in the region with information gathered on-site and contrasted directly with farmers to guarantee representativeness. The alternative system is the average performance of the 28 transitioning farms. This was made to respect the farmers will to avoid being identified in particular. Farmers cooperate with enthusiasm sharing their data and points of view at a personal level, but want to avoid them from going public mainly for safety and security issues, but also for keeping their competitiveness. Therefore, specific data of participating farms is not included as observed in other studies (Bremer et al. 2014; Micheels & Nolan 2016; Merlín-Uribe et al. 2013).

Two field visits where carried out to get firsthand information. This was necessary to develop the indicators to compare the overall sustainability of the management systems. The first one in October 2014, lasted a month to gather data from different sources including local institutions, training staff and farmers. The second one in April 2016 was two weeks long and focused on following up the transition process through personal interviews with farmers and with the project manager.

5.4. THEORY

While the aim of sustaining the support systems of the Earth to enable a future for humankind may be easily understood, identifying effective applications is a more difficult task (Banco Mundial et al. 2001). Assessing sustainability related issues is rather complicated starting from the fact that as a novel scientific discipline it is still under construction and consensus is hard to get (Salas-Zapata et al. 2016; Hecht et al. 2014; Tahir & Darton 2010). Particularly, at local level there are several obstacles for most tools that have been designed and applied at global or national level (Allen et al. 2016). This is rooted in data being normally gathered at these levels and detailed regional and local data is hardly up-to-date or simply not available in many countries, especially in rural areas.

The latter presents another side of the challenge, having pertinent methods for measuring progress towards agricultural sustainability. It is here implied that sustainability *per se* is not something one can measure for it is unrestricted by nature and though the latter leads to an epistemological blurriness as many scholars have pointed out (Salas-Zapata et al. 2016; Wiek et al. 2012; Struik et al. 2014), it also opens the gate for a manifold of disciplines and approaches in agreement with its systemic nature. It is important to apply, adapt and redesign assessment tools such as indicators and models to communicate and evaluate progress as stated before, but also to make sustainability more robust and applicable in response to current global challenges (Miller et al. 2013; Lang et al. 2012; Burford et al. 2013).

The need to evaluate existing plans and programs in terms of changes perceived in the dynamics of agroecosystems is an incentive to develop sustainability indicators suited to the local context with the participation of local communities (Béné et al. 2011). For example, some studies show that economic variables do not significantly affect farm management (Micheels & Nolan 2016), while others find that they are important to determine sustainability, e.g. the socioeconomic position of local farmers and participation in ecosystem services programs or organic production (Bremer et al. 2014; Scialabba 2000; Hejnowicz et al. 2014).

5.4.1. Sustainability assessment Adaptive and Low-input Tool (SALT)

Evaluating for sustainability at field level through physical properties, requires a constant measurement of selected parameters through a long enough period to observe the effects of different management systems in significant variables such as organic matter content, nutrient balance, porosity, water retention or erosion (Congreves et al. 2015; Vukicevich et al. 2016; Ding et al. 2013). These data, complemented with weather records, will determine the sustainability of the system at an agroecological level (Van Der Vossen 2005; Seneviratne & Kulasooriya 2013). The behavior of variables through time is what is relevant, but is not always available (Banco Mundial et al. 2001). The SALT is meant to enable the evaluation of sustainability in these cases.

The process for designing SALT started identifying variables and indicators according to their suitability to the context, ability to provide results in a short time period and flexibility. Following these criteria, indicators that could be easily measured using qualitative and quantitative data were derived to assess on-field the impact in the sustainability of agroecosystems that policies and practices have, as typically needed for interventions in developing countries (Figure 5.1). This was made linking available historical data with information gathered from farmers and field work (Arnés et al. 2013; López-Ridaura et al. 2002; Banco Mundial et al. 2001).

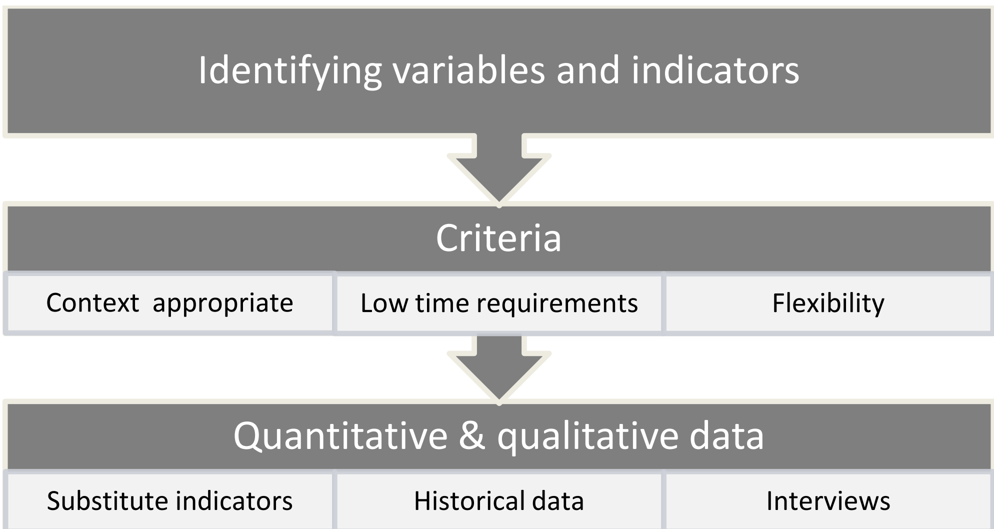

FIGURE 5. 1. INDICATORS SELECTED FOR ANALYZING THE SUSTAINABILITY OF MANAGEMENT SYSTEMS.

In order to integrate the elements of SALT, Figure 5.2 shows how these elements relate and interact with each other. Social indicators at the top of the pyramid, relate to the criteria of self-reliance and equity and adaptability, which are ultimate ends in line with well-being and ultimately happiness (Meadows, 1998). Institutional indicators relate to adaptability criteria and work as intermediate ends. Economic indicators are intermediate means linked to adaptability and productivity. Environmental indicators are at the ultimate means because everything is developed from raw materials found in nature; this is the base of the pyramid meaning they support the whole system in terms of stability, resilience and reliability. The arrows represent the diverse and close dynamics between the four dimensions, attributes of sustainable agroecosystems, ends and means. In sum, this framework allows a clear definition of the sustainability approach and also includes a specific way to assess the performance of the whole system through an integrated scope.

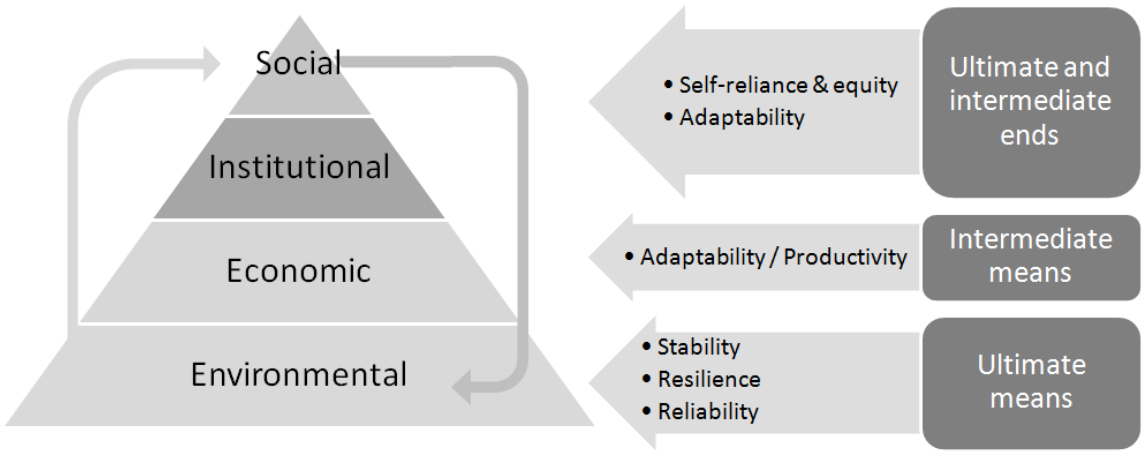

FIGURE 5. 2. RELATION BETWEEN SUSTAINABILITY DIMENSIONS, ATTRIBUTES OF SUSTAINABLE AGROECOSYSTEMS AND MEANS/ENDS FRAMEWORK.

Sustainability assessment tools should be fully adaptive. Following this idea, presented indicators are not intended to be a fixed set since the available data and the context in question will be different for each case. The SALT is meant to allow the incorporation of other variables and criteria relevant to each context as long as the four dimensions and the integrated scope here presented remain. In this particular case, climate change could not be introduced for the measurement of relevant parameters (rainfall, evapotranspiration) and historical data (vegetation cover maps, evolution of water bodies) of localities were not available. In a different scenario, with the objective of assessing the impact over time of a crop management system in the region, perhaps net costs are not as important as land use changes. The latter does not imply that indicators are comparable or substitutable since no aggregation is made; it means that the set is flexible enough to enable the application of the tool to different contexts.

Selection and derivation of indicators was made incorporating the perspective of farmers and the elements of the SALT (see Figure 5.1). These where gathered from field observation, personal interviews and the outcomes from participatory workshops that consisted on three stages: awareness, training and feedback to tailor the transition plan during the two years of the project. All farmers involved in the project (40) assisted, but the ones in transition (28) had an active role.

Table 5.1 shows the attributes of sustainable agroecosystems (column 1) (López-Ridaura et al. 2002; Koohafkan et al. 2012), related to the four dimension model of sustainability (column 2): social, environmental, institutional and economic (CEPAL-ESALC 2004). Then, selected indicators (column 3) tallied to attributes and dimensions, were linked to means / ends (column 4) from the sustainability framework in Figure 2 inspired in Daly's triangle and Max-Neef pyramid (Meadows 1998). The result was a flexible set of 18 indicators that enable a locally-driven integrated assessment of how sustainably are agroecosystems being managed. The source of information for measuring the indicator is also included (column 5).

TABLE 5. 1. ELEMENTS CONSIDERED TO DERIVE THE SUSTAINABILITY ASSESSMENT ADAPTIVE AND LOW-INPUT TOOL (SALT) INDICATORS.

Attribute	Sustainability dimensions	Indicators	Ends / means	Source
Self-reliance & equity	Social	Participation in decision making	Ultimate ends	Interview
		Organized farmers		Interview
		Level of commitment		Interview
		External input dependence		Interview/ field
		Trained farmers	Intermediate ends	Interview/ field
		Adoption of new practices / technologies		Interview/ field
		Policies adequacy		
Adaptability	Institutional	Level of trust in public institutions	Intermediate means	Metadata
		Reliance on subsidies		Interview/ metadata
				Interview
Productivity	Economic	Yield		Interview/ field
Stability		Benefit-cost		Interview/ field/ metadata
		Costs		Interview/ field/ metadata
Resilience	Environmental	Chemical input	Ultimate means	Interview/ field
Reliability		Erosion		Field
		Vegetal cover		Field
		Crop rotation		Interview
		Surrounding natural biodiversity		Field
		Number of species grown		Interview/ field

Semi-structured interviews and quick evaluation methods (observation) were carried out during field trips to gather primary source information. Conclusions from the participatory workshops were accounted as well through documentary research. These are the main sources for measuring the indicators focused on the perception of farmers on soil conditions, conventional versus alternative system outcomes and observed results. Contrasting this information with national and international databases (WHO, 2009; SAGARPA, 2015; FAO, 2016) allowed comparing management systems through the implemented methodology.

The analysis started accounting for biophysical and social resources at the region. Then, relative weights were assigned to each indicator also according to what the farmers stated determining the existence of sustainability boundaries (see Appendix 1).

5.5. Results and discussion

Both conventional and alternative management systems are compared in Table 5.2. Their performance on each one of the selected indicators is analyzed. The units and the score of each indicator are expressed as well.

The conventional system is characterized as monocultures managed by a single farmer who is usually not organized. Chemical inputs mainly external to the farm and the region are used and sustainable practices are only implemented when supplied by government aids and almost entirely restricted to incorporating compost. Croplands have no vegetal cover and therefore show laminar erosion and some rills exacerbated by practices such as burning and/or intensive application of herbicides. Though crop rotation is not usual, generally conventional farmers leave a small space in their farms for self-consumption crops, mainly white or “criollo” maize and in a few cases even beans, chili or squash somehow maintaining the “milpa” tradition. This is an agricultural practice dating back to ancient indigenous people in the Mesoamerican region (Aguilar-Jiménez, Tolón-Becerra and Lastra-Bravo, 2013; González-Esquivel *et al.*, 2015). It is based on the crop rotation of the local diet components such as different maize species, beans, squash, chili and even avocado, tomato and amaranth among others.

The alternative system refers to a farm in transition towards sustainable agriculture within the frame of the project. From 40 farmers in total, 28 are actively in transition, meaning the use of alternative cropping practices such as the replacement of 50% of chemical inputs with natural and organic inputs (composts, microorganisms, etc.), soil conservation, crop rotation and enhancing the active participation and training through workshops.

TABLE 5. 2. INDICATORS MONITORED IN THE TWO MANAGEMENT SYSTEMS: CONVENTIONAL AND ALTERNATIVE IN JALISCO (MEXICO).

Indicator	Units	Conventional		Alternative	
Participation in decision making	Value	Decision making is driven individually	0	Full active participation with voice and vote in all group decisions	100
Organized farmers	Value	Not organized	0	Involved in farmer's organization with voice in DM	75
Level of commitment	Value	Aware about other farmers and how they manage their land considering that they have some influence over each other	25	Concerned with some environmental / social issues related with farm management especially related to other farmers	75
External input dependence	Value	80 to 100% of external inputs	0	40 to 60% of external inputs	50
Trained farmers	Value	Has attended to training from the government and input companies in the past	25	Participates and attends all training sessions	75
Adoption of new practices & technologies	Value	Incorporates compost or other non-conventional practices if provided by the government	0	Soil conservation is accounted; grows more than one crop; substitutes chemical inputs by more than 50%	50
Policies adequacy	Value	There are national guidelines for sustainable agriculture hard to translate to local contexts.	25	There are national guidelines for sustainable agriculture hard to translate to local contexts.	25
Level of trust in public institutions	Value	Farmers distrust some public institutions.	25	Farmers distrust some public institutions.	25
Reliance on subsidies	Value	Farmers rely on subsidies to consider more sustainable alternatives.	0	Farmers require support to continue carrying sustainable agriculture activities.	50
Yield	Ton/Ha	8	75	10	100
Benefit-cost	B/C	1,52	50	2,38	100
Costs (per Ha)	USD*	1 081,32	50	864,76	100
Chemical input**	Value	Chemical inputs of any class are applied as needed	0	Class III-IV chemical inputs incorporating sustainable agriculture techniques	50
Erosion	Value	Evident signs of laminar erosion and some rills	50	Surface shows some laminar erosion	75
Vegetal cover**	Value	Weeds are completely removed or burned and class II-III herbicides are applied	25	Weeds are removed but all residues are incorporated to the soil with mainly organic inputs	75
Crop rotation	Value	No crop rotation	0	Rotates every year with a few months of rest for soil recovery	75
Surrounding natural biodiversity	Value	Surrounded by different crops and wastelands	25	Surrounded by different crops and wastelands	25
Species grown	Value	Monocrop and some species for self-consumption	25	3 species grown	50

*Costs expressed in USD; computed in MXN and correspond to 2015 prices in Mexico.

** Chemical inputs are classified according to the World Health Organization hazard standards (WHO, 2009).

Performance of management systems is shown in Figure 5.3, where a comparison between the alternative and conventional ones was made applying the SALT. The selected 18 indicators were normalized on a 0-100 scale (Annex 1) where 100 represents full sustainability (López-Ridaura et al. 2002). No aggregation is made in an effort to capture the whole agroecosystem performance in terms of sustainability for each case through a spider web graph.

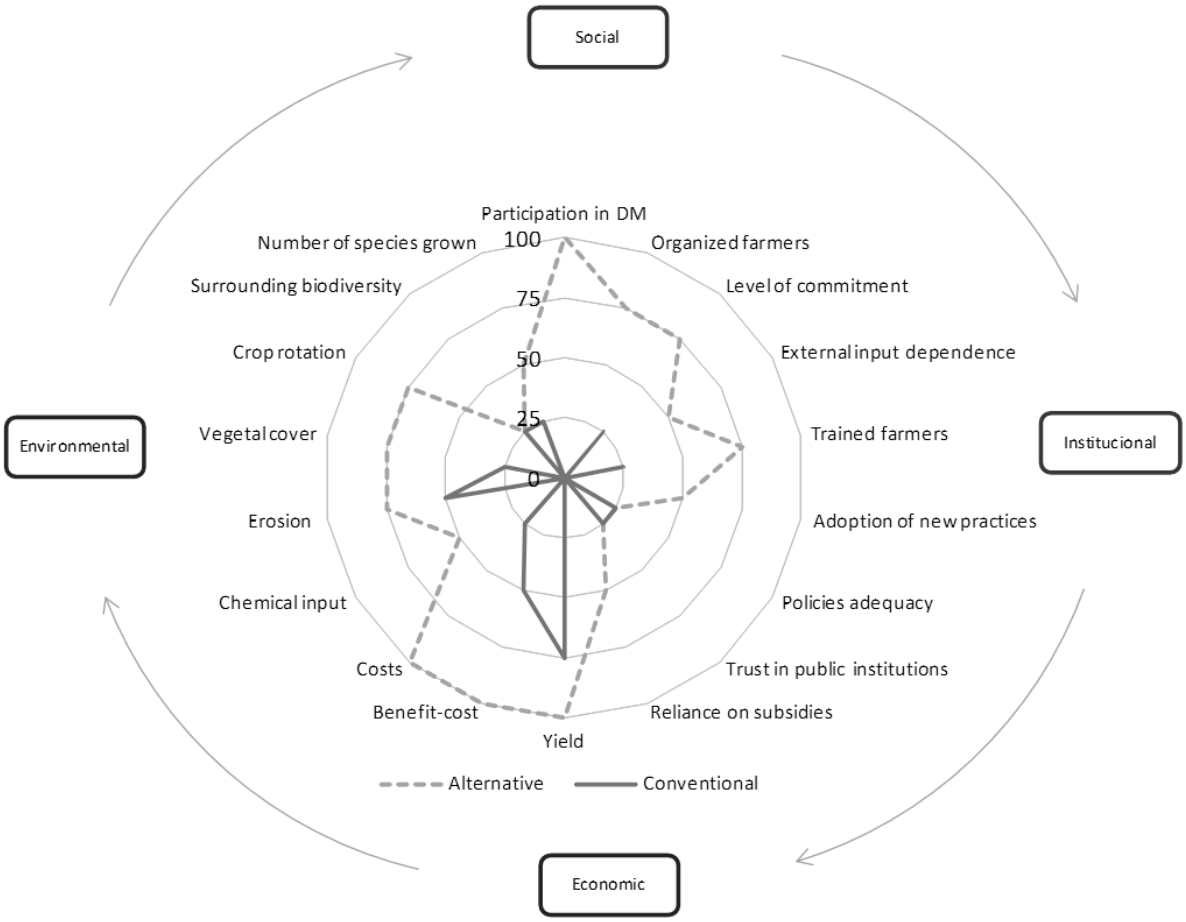

FIGURE 5. 3. SUSTAINABILITY OF CONVENTIONAL AND ALTERNATIVE MANAGEMENT SYSTEMS OF MAIZE IN JALISCO, MEXICO THROUGH IMPLEMENTING THE SALT.

Through the conducted analysis the following results were obtained. In overall terms, the alternative system performed better than the conventional in terms of sustainability. This means in general, that the agroecosystem is more resilient and has a higher adaptive capacity to face changes (Folke, 2006; Altieri *et al.*, 2015).

Economic indicators showed higher values for the alternative system, due to lower costs and higher yields that translates in a 40% of economic improvement (savings plus profits). Appendix 2 shows a detailed economic comparison between these management systems. To be noted is that the analyzed period 2015-2016 was characterized by higher cereal production including maize in the country at record levels (FAO, 2016).

Social indicators performance stands out in the alternative system due to the influence of a project that was being carried out at the moment with participation, commitment, dependence on external inputs and training as important axis of the intervention. Also, the fact that farmers implementing the alternative system where already organized had an impact in this dimension.

The case of environmental indicators is similar to the social dimension. In general terms, the alternative system performed better primarily for the incorporation of organic inputs, the reduction by half of chemical ones, keeping some vegetal cover and the rotation between three species in croplands. These activities were also enhanced by the project. However, their impact was not enough to make a difference in the surrounding environment where both systems performed equally.

The institutional dimension was almost the same for both systems because the perception of farmers regarding public institutions is deteriorated due to inequalities towards rural areas, which can be traced back to the changes in agrarian policies in 1982 (Avalos & Graillet 2013; Wiggins et al. 1999) and other social and security issues (Morris & Klesner 2010). A specific contradiction was found in this dimension. On the one hand, farmers mistrust the public administration and institutions in general terms. This is rooted mainly in corruption and hidden agendas observed over the time (Rodríguez 2013; Dzhumashev 2014) as collected in conducted interviews. On the other, farmers express that they rely on public aids for continuing practices related to sustainable agriculture and also demand ways to differentiate their products from conventional other than the restrictive certification processes (Koohafkan et al. 2012). Because of the actions that farmers have already taken in the alternative system, that the project did not provide economic aid and their demands being related to continue transitioning towards sustainable agriculture (not to start with it), reliance on subsidies was considered lower in the alternative system.

It is noteworthy that the positive performance of the alternative system in all dimensions is mainly because of a lack of tradeoffs between indicators–costs and yields for example– which is explained (in accordance to farmers themselves) in the quick response of impoverished soils to the application of microorganisms and other organic inputs. Also important is the reduction of land preparation labors that where limited, the abandonment of full technological packages applied by conventional farmers plus a year that was especially productive in the region. The frame of the project also absorbed costs related to training and adoption of new practices and techniques as well as farmers being organized reduced machinery and seed related costs (see Annex 2). Finally, the alternative system combines chemical and organic inputs and therefore behaves differently than the organic systems more commonly contrasted in literature (McGee & Alvarez 2016; Van Der Vossen 2005; Astier et al. 2011).

Farmers modify the way they manage resources according to more than ecological variables so heavily incorporated when analyzing sustainability. Therefore, this research confirms that socioeconomic variables such as the price of technologic packages, government incentives, results from other farmers and the level of trust on implemented activities must be addressed both to develop as to evaluate interventions. This is even more important at local level.

Considerations on the level of appropriation of sustainable agriculture based actions by farmers must be included because it was identified as a determining factor to grant the continuity of adjustments and/or changes throughout time. Acceptance from farmers is essential for the sustainable management of an agroecosystem for they will carry on with it. Their inclusion on the decision-making process is then mandatory.

In general, results show high possibilities of farmers continuing with the alternative system practices. Nevertheless, the analysis did not show any evidence that supports the idea of farmers carrying activities one step further, in terms of sustainability, on their own. For example, none of the farmers engaged in leaving 1 ha free of chemical inputs because of the uncertainty and mistrust generated by the delays of the project and moreover by its interruption. This is rooted in 1) their expectancy of obtaining public aids (Merlín-Uribe et al. 2013); 2) a lower visibility of environmental and social benefits than economic ones (Burford et al. 2013; Srivastava et al. 2016); and 3) skepticism of farmers towards change (Binder et al. 2010). The latter also explains why transitioning practices here described were not replicated in surrounding farms despite the positive outcomes.

5.6. CONCLUSIONS

Overall, the SALT methodology proved to be suitable for assessing agroecosystems sustainability at local level providing a practical and holistic approach. The latter is confirmed through clear results when comparing different management systems obtained with very low time and resources requirements. This is valuable for local administrations and stakeholders that do not usually count with large budgets or timelines to make decisions especially regarding sustainability in developing countries.

Sustainability indicators such as the state of natural environment, land use evolution, pest incidence or nutrient balance of the soil, were not directly incorporated. Direct parameter measurement was not carried out for: the limited availability of full microelements analysis (only three labs in the country are able to) and consequent soil data at farm level; the lack of a reference system with the past; and the timeframe. However, using substitute indicators is useful and even necessary when investments and research are made under restricted resources. This becomes mandatory in the Mexican context, but given the current global scenario it is the norm rather than the exception. Indicators must be derived according to the local dynamics observed in the analyzed sustainability dimensions. This is allowed in the SALT by the use of a non-fixed set of indicators.

Considerations on sustainability started from concerns over natural resources. Therefore, the environmental dimension generally predominates when deriving indicators. In addition, economic analysis determines the viability of a project. These factors keep leaving behind social analysis generally due to arguments such as the corresponding increase in complexity, resources and time. However, the present research showed that if considered from the start when developing projects and interventions, costs do not necessarily increase.

The cooperation with the consultancy Campo Orgánico Empresarial (Organic Rural Bussinesses) in charge of managing the project to enhance sustainability in agriculture practices facilitated gathering first-hand information, data and direct interaction with farmers. However, it was also an obstacle for several fund delays and schedule setbacks on the project that impeded farmers from making a more profound transition. Most importantly, the abrupt interruption the project after two years instead of four, made impossible to broaden the analysis through an ex-post evaluation within the research time frame. This would be the main line to follow-up in future research and is especially important to corroborate the suitability of the SALT.

As a concept in constant evolution, sustainability assessment tools should be made to adapt to changes in application and interpretation. In this case, future research could search for ways to incorporate dynamic analysis and a more systemic perspective into the SALT. Also, a different configuration of the tool geometrically aggregating indicators by dimension could be made to stress the non-substitution between them. Other research lines to be explored include incorporating climate change variables and scenarios, energy consumption analysis, microelements monitoring and cross-case studies.

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6 SYSTEMS THINKING: FUNDAMENTALS TO BRING THE WHOLE BACK TOGETHER

ABSTRACT

This chapter is focused on broadening the applications of the Sustainability assessment Adaptive and Low-input Tool (SALT). The objective is to enable a more dynamic assessment with clear outputs for stakeholders to drive policies and decision-making processes towards a sustainable agriculture. It is an effort to bring the whole back together after deriving and evaluating indicators that, although necessary for assessing where the management of agroecosystems stands in terms of sustainability, involves a simplification of the system. In other words, the analysis was made from the inside-out: first the elements to understand the state of the system and then these elements were related to each other to understand how the system works. The latter was achieved with the analysis of causalities and relations between the elements of the system through the incorporation of fundamentals from systems thinking approach. It is intended to be as close as possible to a dynamic assessment within the limits of the present research.

Keywords: sustainability assessment, local dynamics, agroecosystems, decision-making processes, systems approach.

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6.1. Introduction

Sustainability raises awareness for the fragile stability of human systems. Its basic definition implies the need for constraining present actions not to compromise future wellbeing (WCDE, 1987). By focusing on the future, has gained strength as a multidimensional normative approach using predictive methods to shape policies and actions into more responsible and coherent ways (Benessia *et al.*, 2012). It has also been translated into a scientific discipline that, by nature, is always attempting to grasp complexity (Salas-Zapata, Ríos-Osorio and Mejía-Escobar, 2016). Therefore, it has become a systemic approach that is now very prominent in scientific literature and in political agendas around the world (Binder, Feola and Steinberger, 2010). Particularly, its repercussion in the public policy arena has also made it a policy goal (United Nations, 2015).

However, this "work for a better future" perspective has also lead to broaden the gap between present and future, making it harder to design and implement concrete commitments and actions that can be translated to an actual transformational process. The fact that after more than 40 years sustainability is still something to wait for, proves the ambiguous and multifaceted relation that has with social, scientific, technologic and governance fields (Benessia *et al.*, 2012). This translates in governments having to choose realistic ways to achieve ambitious sustainability targets in short time while policy-makers trying to assess implications of programs and interventions in the long-run.

In this regard, there is a need for tools and methods that can be useful in the decision-making process (Hák, Janoušková and Moldan, 2016). The actual state of sustainability assessment is characterized by the existence of several tools and methods carried out by different users with diverse backgrounds and purposes. There are as many sets of sustainability indicators as organisms and research groups that develop and implement those sets (Hak, Kovanda and Weinzettel, 2012), showing the low level of commonality that is rooted in the lack of consensus on the very concept of sustainability (Salas-Zapata, Rios-Osorio and Trouchon-Osorio, 2012; Wiek *et al.*, 2012).

Nevertheless, the review of specialized literature revealed a research gap in regards of a need for flexible and adaptable tools that reflect the dynamic nature of agroecosystems to be applied at local level in developing countries, where diversity is greater both in contexts as in data availability and information flows (Giest and Howlett, 2013; Constantin, Ştefănescu and Kantor, 2015; Delmotte *et al.*, 2016; Schut *et al.*, 2016). Then, a lack of proper solutions for making available the right information at the right time for decision-makers at local level is observed.

Thus, sustainability is understood as a normative approach composed by multiple dimensions a scientific application, a systemic approach and a policy goal. However, it cannot be measured through scientific methods because of its complex multidimensional nature and unpredictable behavior.

The objective of this chapter is to narrow down the breach between a practical yet reductionist measurement of indicators and a complex reality regarding sustainable agriculture through systems thinking. This is pertinent for the interdependent nature of agroecosystems and the need to state and ponder how sustainability policies and projects are really impacting the way these systems work at local level.

The chapter aims to describe how to conduct a results-based evaluation with a systems-based approach specific to the local context through a flexible and adaptive method: the Sustainability assessment Adaptive Low-input Tool (SALT). The main goal is to present an assessment tool kept simple enough to lower the barriers, making multi-dimensional field analysis accessible to local contexts where capacities and resources are diverse and fluctuant both between and within cases (Goergens and Kusek, 2010). The SALT was broaden to be applied in the post-evaluation of the project "Promotion and development of organic agriculture for grain producers in Jalisco, Mexico" as case study (Calleros-Islas, 2017b). This project was conducted from 2014 to 2016 and the collaboration with Campo Orgánico Empresarial (Organic Rural Bussiness) the consultant agency that carried out the project, allowed us to gather first-hand information on the management of agroecosystems in the region. The conducted analysis is based in the interviews and field visits that generated original data for the present research.

The chapter is structured as follows: a first section explains the conceptual framework based in systems thinking and decision-making. In a second section methods are presented describing the way in which the assessment tool was driven towards dynamic analysis. A third section is dedicated to the case study on the post-evaluation of the project: "Organic farming promotion and development for grain producers in the state of Jalisco". The fourth section presents the results and discussion, followed by the conclusions.

6.2. CONCEPTUAL FRAMEWORK

The conceptual framework of the second stage of the SALT is rooted in two main disciplines: systems thinking and decision-making. Their importance in the analysis of sustainability is found in the need to ensure a holistic scope through systems thinking, and putting its principles to practice through decision-making.

If progress towards sustainability is to be evaluated, interconnected dimensions must be assessed simultaneously. Then, criteria must be applied in a practical way to provide inputs for decision-making. A tool that does not apply criteria in a practical way is not really contributing to sustainability (Sharifi and

Murayama, 2013). This can be achieved implementing a holistic and integrated framework and the settlement of assessment criteria that can be adaptable to specific contexts.

The search for new methods that fulfill these requirements makes sense because, as stated in the introduction, in order to make sustainability an actual driver of decision-making processes stakeholders need reliable assessment inputs. Four concerns arise when assessing sustainability that perform as drawbacks at local level and are more marked in developing countries: a) the need for data that is not available; b) simplified outputs for communication with decision-makers; c) understanding the behavior of the analyzed system as a whole with a representation of its interactions through a systems thinking perspective; and d) tools not only to monitor but to steer up a systems change through time in order to trigger a transition, in this case towards sustainability. These concerns can also be used to evaluate the performance of assessment tools.

6.2.1. Systems thinking

In general terms, a system is defined as a set of interrelated or interacting elements. Systems thinking is understood as a holistic scope for studying and understanding systems of any kind from multiple angles.

From this perspective emerges the concept of the social-ecological system (SES). This approach is based on analyzing society – including economy and institutions – and ecology as one single system (Ostrom, 2009) instead of the "parceled" vision that has prevailed in science for more than two centuries (Gallopin *et al.*, 2001; Naredo, 2001; Munda, 2004) especially since the hegemony of neoclassical economics (Costanza, 2003).

SES theory states that economy, society and the environment depend on each other (Ostrom, 2009). Their interrelation is so close that makes little sense trying to understand these dimensions separately (Wilson *et al.*, 2013; Frey, 2016). Agroecosystems are the object of my analysis, being understood as agriculture based SES: agricultural systems that include social, economic, institutional and ecological dimensions and dynamics.

6.2.2. Decision-making

Decision-making process regarding sustainability must deal with complexity and variables interdependence. Along the process, policy-makers, planners and development workers will need standards and tools to address these issues in a way that improves the compatibility between the local and the global spheres. Rethinking how to assess sustainability analyzing and monitoring initiatives, can contribute to the latter (Grimble and Wellard, 1997).

Meanwhile, public institutions must have skills to negotiate with different actors with diverse perceptions to count with their support. Along the process, the focus is set to find a balance between getting enough support from the parties involved and satisfying the goals offered by a given alternative (Runhaar, Dieperink and Driessen, 2006). Hence, when choosing between alternatives to achieve greater sustainability the importance of counting on reliable information is shown.

To develop appropriate methods to assess sustainability, they should have both a robust scientific support and a broad perspective of the SES to provide sufficient information and evidence for stakeholders to enhance sustainability in decision-making processes and policy design (Cornell, 2011). These factors lead to settle a governance where multiple actors and sectors are involved, stepping aside the traditional hierarchical government model in order to decentralize the decision-making processes (Runhaar, Dieperink and Driessen, 2006), all which is required in order to integrate sustainability into policies.

Decision theory sets three different ways to make decisions following the level of definition and clear understanding of the process: structured, semi-structured and unstructured. Structured decision-making processes are characterized by routine; this enables the following of standard procedures on its operation, data processing and implementation of management models. Unstructured decision-making processes relate to issues that cannot be taken into account with standardized procedures and are mainly based on human perception, knowledge or intuition and have to be addressed adaptively (Liu, 2007).

The majority of sustainability related policy and decision-making processes tend to be unstructured and interrelated with each other. This roughly means that environmental decisions impact society (and economy since is part of social dynamics) and vice versa. Nevertheless, dimensions are usually assessed separately through a myriad of methods and tools by researchers and policy makers. These considerations are why the impact of an integrated assessment tool in decision-making processes related to enhance and facilitate channeling efforts towards sustainability is important.

6.3. METHODS

There is a great amount of experience in sustainability research and policy making that needs to be reflected into more integrative and plural assessment tools. Methods that allow assessing and accounting for all sustainability dimensions simultaneously are the ones useful for policy-makers and communities to strengthen or change characteristics of agroecosystems to design pathways to enable achieving positive future outcomes (Cornell, 2011).

Accordingly, indicators must be flexible and adaptable, even though perfect comparability is lost in the process. However, I considered that the current state of the art in sustainability assessment already offers enough (and even too many) tools that offer comparability between different cases and contexts (Runhaar, Dieperink and Driessen, 2006; Monterroso *et al.*, 2014; De Olde *et al.*, 2016). On the contrary, few of them are flexible enough to adapt to the changes in a system through time, which is a more appropriate input for assessing the management of agroecosystems (López-Ridaura, Masera and Astier, 2002; Altieri, Funes-Monzote and Petersen, 2011; Sharifi and Murayama, 2013). Taking into account that sustainability is a long-term goal interventions require monitoring tools that also adapt to changes in the behavior of the system.

Transferability of applied methods is growing in recognition among the scientific community as crucial attribute of research results. Is no longer enough to state that results can be replicated and even scientific publications are encouraging authors to share their data towards greater transparency in research development (i.e. SCOPUS journals). In agreement to this, previous and present analysis show the whole process that was followed to develop the SALT in order to enhance more transparent and close to end-users approach in research (Calleros-Islas, 2017a). It is also considered that in sustainability related research transferability is especially necessary because of the difficulty of reaching consensus and real impact in policies and decisions, and even more, for local assessment in developing countries.

The previous application of the SALT (Calleros-Islas, 2017a) allowed a multi-dimensional and adaptive analysis but without accounting for dynamics between the assessed elements. This limited the potential applicability to follow-up results as direct inputs for decision-making.

An effort is made here to incorporate a dynamic application that not only adapts to different cases but that allows the assessment of systemic changes to monitor and analyze the behavior over time of each element and of the system as a whole. The latter is achieved correlating the elements that the indicators represent so that shifts and progress can be measured allowing the system to adapt to moving and evolving targets, just like observed in the policy arena. Indicators are then understood as visible outputs of the system elements and the linkages between these elements tell us how the system behaves (Jerneck *et al.*, 2010; Kerkhoff, 2013; Keating *et al.*, 2017).

Answering to this need for adaptable assessment tools and context specific implementation methods, this second stage of the SALT is meant to help in the critical process of prioritizing policies and directing programs towards long-term impacts as required for enhancing sustainability. This makes sense before the need to efficiently allocate scarce resources (Bossel, 2001; Hu *et al.*, 2016).

Table 6.1 shows on the first column the indicators that were used to assess the impact of the project at farm level. The set of indicators is flexible to allow the changes within an agroecosystem through time. To incorporate these dynamics, on the third column the elements that these indicators represent are shown according to systems thinking criteria (second column) to allow the analysis of interrelations and influences between them.

TABLE 6. 1 INDICATORS SET IN RELATION TO SYSTEMS THINKING CRITERIA AND ELEMENTS REPRESENTED.

Indicator	**Criteria / attributes**	**Elements**
Participation in decision making	Adaptive capacity	Participation
Organized farmers		Organizational form
Level of commitment		Commitment with environment (social & natural)
External input dependence		Self-sufficiency
Trained farmers		Training adequacy
Policies adequacy	Institutional readiness	Policy framework for sustainability
Level of trust in public institutions		Interaction with public administration
Reliance on subsidies	Coping capacity	
Adoption of new practices / technologies		Practices & technologies
Yield		Maize production
Cost-benefit		Economic balance
Costs		
Chemical input		Water quality
Erosion		
Vegetal cover	Stability, resilience, reliability	Soil quality
Crop rotation		
Surrounding natural biodiversity		Biodiversity
Number of species grown		

The dynamics between the elements of the system are analyzed through the application of the Vester matrix (Vester, 2012). The Vester matrix is a tool commonly used in problems analysis that is rooted in systems thinking theory. This tool allows us to identify the elements of a system and prioritize those that are more critical to the dynamic of the whole system. The latter is achieved by crossing the elements in terms of the influence exerted and received by each element related to the rest in a matrix of causality. The result is a clear classification of causal relations between the elements.

6.4. Case study

The SALT was implemented in the project "Organic farming promotion and development for grain producers in the state of Jalisco" that was conducted in Jalisco, México (Calleros-Islas, 2017a). The aim of the project was to enhance a more sustainable agriculture of basic grains through changes in the management of agroecosystems in three different municipalities located in the agricultural valley of the state. The approach of the project was participative and based in agroecological principles. Interventions were directed to three organizations of medium-size farmers (5 to 20 ha). A first goal was the improvement of cost-benefit relation for farmers, followed by soil recovery and the reinforcement of using local agricultural inputs.

It is important to mention that farmers were the ones that established the links between the elements of the system and assigned weights for these as well. This was achieved processing the information gathered from semi-structured interviews with farmers from the three participating organizations. These same interviews allowed the compared assessment made in the previous stage (see Chapter 5). From a total of 40 participating farmers, only 28 were actually committed to the project and with 5 of them two interviews were conducted a first one in October 2014 and a second one in April 2016 to follow-up.

Table 6.2 shows the matrix of relations between the elements of the agroecosystem. The active weight of each element is in the rows of the table and refers to how much influence the element has over the rest; the passive weight is found in the columns meaning how much influence the element receives from the rest. For example, biodiversity has an active weight of 16 but a passive weight of 23, meaning that is more influenced from the other elements than the influence it has over them. Therefore it is inferred that biodiversity is an element that producers considered as not actively affecting the system as a whole but is rather affected by it. It can even be said that they consider biodiversity as a more independent element.

The nomenclature of the matrix is shown below.

Nomenclature	
N/A	0
Low or no influence	1
Influence	2
Strong influence	3

TABLE 6. 2 MATRIX OF INTERRELATIONS BETWEEN THE ELEMENTS OF THE AGROECOSYSTEM.

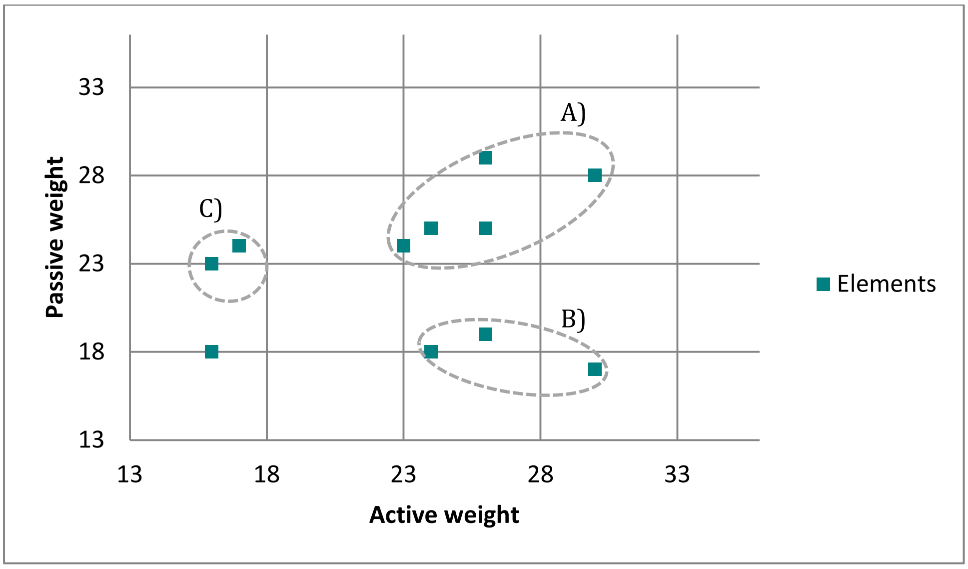
Active → Passive ↓	Economic balance	Self-sufficiency	Practices & technologies	Interaction with public administration	Maize production	Water quality	Soil quality	Training adequacy	Participation	Policy framework for sustainability	Commitment with environment (social & natural)	Organizational form	Biodiversity	ACTIVE WEIGHT
Economic balance	0	3	3	2	3	2	2	3	3	2	1	1	1	26
Self-sufficiency	3	0	3	3	3	3	3	2	3	2	3	1	1	30
Practices & technologies	2	2	0	2	3	3	3	1	2	1	3	1	3	26
Interaction with public administration	1	3	3	0	1	1	1	1	1	2	1	1	1	17
Maize production	3	3	3	3	0	1	1	1	2	1	1	3	1	23
Water quality	1	3	2	2	3	0	3	1	1	2	3	2	3	26
Soil quality	1	3	2	1	3	3	0	1	1	2	3	1	3	24
Training adequacy	3	3	2	1	3	3	3	0	3	1	3	2	3	30
Participation	1	2	2	2	1	1	1	1	0	2	1	2	1	17
Policy framework for sustainability	1	2	2	3	1	2	2	3	2	0	3	1	2	24
Commitment with environment (social & natural)	1	2	3	2	1	3	3	1	2	1	0	2	3	24
Organizational form	1	1	2	2	1	1	1	1	3	1	1	0	1	16
Biodiversity	1	1	2	1	1	2	2	1	1	1	2	1	0	16
PASSIVE WEIGHT	19	28	29	24	24	25	25	17	24	17	24	18	23	

6.5. RESULTS & DISCUSSION

The matrix (Table 6.2) shows the causal relations between the elements of the agroecosystem. These relations can be either active or passive. An active relation means that there is an influence from the selected element to the rest. A passive relation means how much the element is influenced by the rest.

To facilitate the analysis of the results, Graph 6.1 shows the active and passive weights of each element. It is important to remind that weights were assigned by farmers through unstructured interviews conducted on-field. The scale is according to the minimum and maximum score available which is between 13 and 36.

FIGURE 6. 1 ACTIVE AND PASSIVE WEIGHTS



The analysis will first be centered in the elements with higher active and passive weights (Cluster A: right upper quadrant in Figure 6.1), since the aim is to generate clear outputs to facilitate decision-making processes and policy prioritizing towards a more sustainable agriculture. These are identified as the critical elements.

Self-sufficiency stands out as the element with greater potential to trigger changes in the system since it has a high active and passive weight (30, 28). This means that it is the central element to be accounted for policy design as well as the main element to monitor and evaluate the performance of whole system according to the perspective of farmers. This can be translated in farmers observing self-sufficiency as a determinant element and also the connection that has with the rest of the system.

The performance of this element in the matrix is showing that farmers understand that self-sufficiency is highly dependent towards the system and at the same time, it has the higher potential to enhance the performance of the agroecosystem towards sustainability. This finding is a remarkable evidence of how systems thinking can bring tangible outcomes that can be used as inputs for decision-making processes.

The other critical elements in Cluster A are: practices & technologies, water quality, soil quality, commitment with environment and maize production. This is consistent with their potential to improve or deteriorate the performance of agroecosystems and the fact that these are commonly used indicators to assess their management.

The elements that show a high active weight and low passive one are identified as influencers to the dynamic of the system (Cluster B: right lower quadrant in Figure 6.1). They have the potential to drive shifts and changes. In this case, what farmers identified as the most influencing elements are economic balance, training adequacy and policy framework for sustainability.

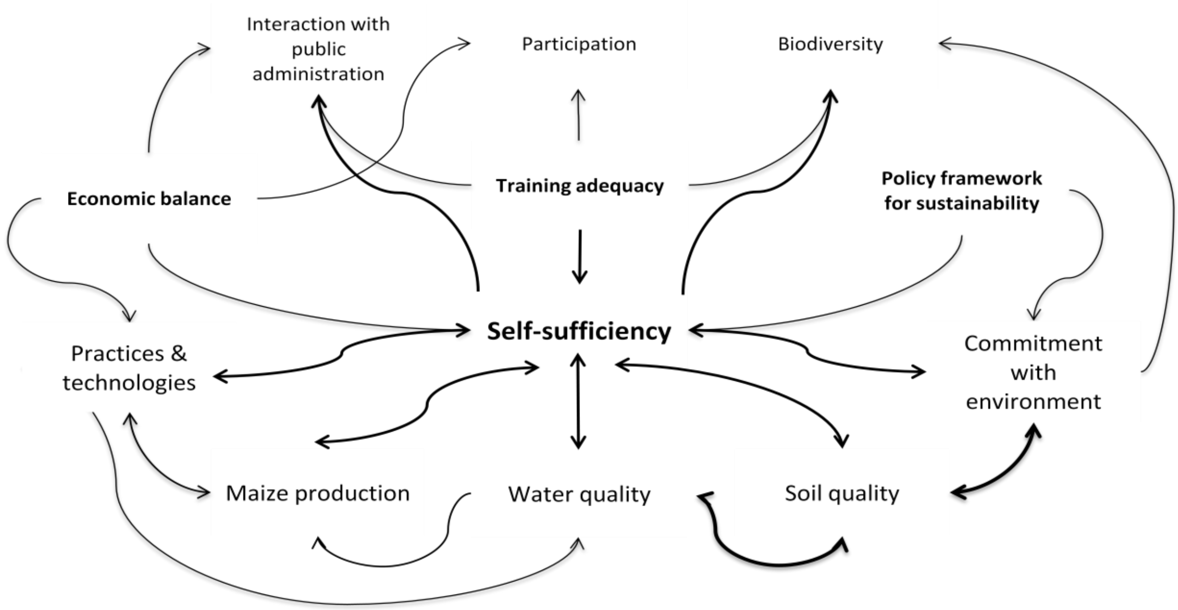
These are key elements that should be taken into account because they cause the behavior of the system. Active elements can be easily translated into targets in decision-making processes. These elements have, according to farmers, the greatest potential to drive changes to the system. This result is consistent with the outcomes from the project “Organic farming promotion and development for grain producers in the state of Jalisco”, that even with low institutional support and a small budget (e.g. farmers had no economic support at all) got to considerably improve environmental indicators in participating farms based in sustainability policies directed to participatory training in organic management activities and improving the cost-benefit ratio (Calleros-Islas, 2017a, 2017b).

The elements with high passive and low active weight behave as predictor variables (Cluster C: left upper quadrant in Figure 6.1). This means that they receive higher influence from the rest of the system but provide no causal influence. They can act as indicators to aid in progress evaluation and monitoring or showing trends in regards to the objectives derived from the active elements.

Interaction with public administration, participation and biodiversity, have greater potential as predictors. If indicators are derived to show progress in the interaction with public administration, participation and biodiversity, they will in turn show how the elements that influence them are performing. However, it is considered that with weights around the media (24 and 23) the potential of these three elements to offer an approximation of the elements that influence them should be observed in practice. It is also likely that farmers are not clear about the connection between these elements and the agroecosystem, which can also be clarified through practice.

There is also one element considered as indifferent to the performance of the agroecosystem, the organizational form. This is due to the fact that farmers have a low level of trust among them and between them and public institutions. For example, some of the farmers stated that anyone can lie in regards to quality and management reports. They also are suspicious on public institutions and farmers organizations because of their involvement in previous corruption cases and low commitment in the long run. As a result, this element may be excluded from the analysis comparing the results in future participatory workshops. Accordingly, this element was not included in Graph 6.2, a first dynamic representation of the relations between the elements of the agroecosystem. The direction of the arrows show observed relations and the thickness of the lines represents how strong is this relation.

FIGURE 6. 2 MAP OF THE DYNAMIC RELATIONS IN THE AGROECOSYSTEM.



Elements with passive weight can also be indirectly targeted by enhancing influencers. According to the matrix results, by targeting self-sufficiency effects are generated in practices and technologies, water and soil quality, commitment with the environment and maize production (base of Figure 6.2).

The elements with lower passive weights were training adequacy, policy framework for sustainability, organizational form and economic balance. In general terms, this is due to their more independent nature like in the case of training adequacy and economic balance with a clear active role in the agroecosystem (top of Figure 6.2). However, in the case of the organizational form this is because farmers see this element as more external to the system and do not appreciate any significant relation since it has a low active weight as well.

The case of the policy framework for sustainability can also be a consequence of the disappointment produced with the interruption of the project and the low expectations medium sized farmers place in public institutions in general (Calleros-Islas, 2017b).

6.6. Conclusions

The present chapter is an example of how a simple step towards systems thinking – which added more complexity to the scope of analysis – changes everything. In this particular case, it was possible to make visible how the interventions derived from the project "Organic farming promotion and development for grain producers in the state of Jalisco" had an impact on the actual management of agroecosystems and on the farmers perception of sustainability.

The performance of the second stage of the SALT in regards to the identified quality criteria had the following results:

a) Proved to be a viable alternative when data is not available or important data gaps are found, which is typical in developing countries at local scale.

b) Delivered simplified outputs for communication with decision-makers since the active/passive weighting of the relations between elements states what stakeholders, in this case the farmers, consider important; it also helps prioritizing policy targets in a very clear way through the identification of critical elements.

c) The matrix of relations and corresponding graphs, delivered a representation for understanding the behavior of the agroecosystem with a systems-based approach. This allowed a dynamic assessment of its performance in terms of sustainability. However, it is considered that future research can focus in providing a better representation of the system dynamics.

d) As for the capacity of triggering a transition towards sustainability, preliminary findings support that the tool has potential for this matter. This point exceeds the limits of the present analysis and is identified as a research line to be followed with further studies.

The main setback was the unavailability of continuing on-field research due to the interruption of the project as a consequence of the administration cutting back the budget to less than a tenth part of what was originally allocated. The latter generated discomfort among farmers and prevented interviewing all participating farmers and the presentation of results in a participatory session to allow direct feedback.

In future research farmers will co-decide the shifts in the indicators set according to what is actually relevant for them. The SALT will then show its true potential allowing visualizing and assessing results in a dynamic way. This will also include accounting for changes in relations, weights and relevance of the elements of the agroecosystem. Facing these results, it is considered that the ability of adapting to changing environments in a method to assess sustainability is required.

It has been shown that although all elements are connected to all others forming the building blocks of the agroecosystem, the weights from the SALT matrix can lead to a prioritization process between those elements. This is possible after identifying the nature of each one of the elements.

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7 CONCLUSIONS

The present thesis aimed to propose a way to close an identified research breach concerning two main issues: 1) the mismatch between a rich and multidimensional theory and segmented results and applications; and 2) the lack of sustainability integrated and adaptive assessment tools that can be applied and driven at local level. In this chapter, obtained results will be contrasted with the aims and objectives altogether with future research lines and applications to conclude my research evaluating the level of congruence achieved.

The main objective was to answer these questions through the design of an adaptive and integrated sustainability assessment tool to be driven at local level. This objective was fulfilled with the design and implementation of the Sustainability assessment Adaptive and Low-input Tool (SALT). The latter was made under the hypothesis that if a tool for integrated assessment includes a systemic framework of sustainability then, is useful for consolidating the sustainability approach bringing tangible results to drive decision-making processes at local level.

The hypothesis acceptation or rejection will be shown following the results from the specific objectives.

1. Analyze sustainability frameworks to select those that better reflect the interrelated and multiple dimensions of the concept to consolidate the sustainability approach.

Reviewing sustainability frameworks opened a way to strengthen the operational capacity of the sustainability approach because they provide a capacity to structure, interpret and integrate information to help decision-making processes. It was found that a framework with a systems-based approach, can work as a base in finding ways to overcome the complex challenges faced worldwide and the fragmentation of sustainability dimensions observed in applications and interventions.

2. Carry out a diagnosis on sustainability assessment tools that generate clear inputs for guiding decision-making processes, policies and actions towards sustainability.

Sustainability assessment has been largely implemented as shown in the reviewed literature with different inputs for decision making processes. These can be more or less useful for enhancing the communication of results and providing robust information for stakeholders. The conducted diagnosis showed that tools that incorporate sustainability in a broader sense were the integrated assessment tools that performed better in generating clear and useful information to help prioritizing more sustainable choices.

3. Incorporate a systemic sustainability framework into an integrated assessment method in the design of an adaptive tool for assessing sustainability at local level with low input requirements and high level of flexibility.

The Sustainability assessment Adaptive and Low-input Tool (SALT) was designed after starting the case study with on-field work. The latter, enabled to design the tool around observed needs. In this case, a need to fully conduct the assessment of sustainability at local level was found. This was translated in the use of substitutive indicators derived from personal unstructured interviews and on-field observation. Emphasis was placed on local farmers and their ability to evaluate the performance of agroecosystems. The final outcome was a tool that allows a dynamic assessment through time by implementing a flexible indicator set that is conducted to accommodate to the needs and priorities of farmers and stakeholders, and also to trends and challenges in each stage. This is a novel approach to sustainability assessment, since comparability between different cases has been a largely preferred characteristic in this field.

4. Apply the tool in a case study conducting field work to gather first-hand information and directly observe and evaluate results at local level.

Being maize the main crop in Mexico and Jalisco the largest producer of rain fed maize in the country, the case study focused on the project "Organic farming promotion and development for grain producers in the state of Jalisco". Although the project was not completed due to budget cuts, it allowed local farmers to start a transition towards sustainable agriculture, mainly through soil conservation practices and chemical input substitution, which in turn, allowed a more favorable cost-benefit ratio for farmers and a lower grade of dependence from the exterior. In general terms, assessed results showed that participating farms with this alternative management system, performed better than conventional farms in terms of sustainability and resilience.

The performance of the SALT was valued according to the next quality criteria: applicable when data gaps are found; delivers simplified outputs; counts with a dynamic representation based in systems-thinking to evaluate progress; and, has the capacity of triggering a transition towards sustainable agriculture. The SALT proved to be a viable alternative when data is not available or important gaps are found, a typical characteristic of local contexts in developing countries. Delivered simplified outputs for communication with decision-makers both from the evaluation of the whole agroecosystem as from the active/passive weighting of the relations between elements; these two stages clearly state what the farmers identify as priorities setting a course for sustainable policy targets.

A representation of the agroecosystem dynamics was made through the matrix of relations between elements to follow-up change through time in the system. Preliminary findings support that the SALT shows potential to trigger a transition towards sustainable agriculture, but this point exceeds the limits of the present analysis.

In conclusion, the hypothesis that a tool for integrated assessment with a systemic framework of sustainability is useful for consolidating the sustainability approach to drive decision-making processes and bringing tangible results at local level can be validated and accepted.

7.1. Limitations and setbacks

A paradox is found in decision-makers having to meet short and medium term objectives and sustainability being a long-term goal. This fight against immediacy is one of the greatest obstacles for sustainability in general and sustainable agriculture in particular. The latter is due to the mismatch between an approach that sets goals with present applications but future effects.

Regarding sustainability integrated assessment, the main setback is the fragmentation observed in many of the analyzed tools. This is rooted in the prevailing scientific method based in specialization which is not to be fully exchanged but rather complemented with multi and trans-disciplinary approaches.

The design of the SALT also encountered several obstacles. The most important one was the unavailability of extending field-work to conduct a participatory workshop to share, contrast and evaluate the assessment results with farmers. Also, research was limited in time and economic resources which prevented carrying chemical soil analysis. The latter impeded getting tangible data on how actions really impacted the soils composition and biological activities. This is why other frequently used sustainability indicators such as the state of natural resources, land use evolution or nutrient balance of the soil, were not directly incorporated.

In the specific case study, farmers are imbedded in the immediacy of agricultural seasons and cropping stages which is not compatible with public administration deadlines and periods. This means that farmers cannot wait for programs to be accepted and resources to be allocated to continue with their activities and the much needed technical advice usually arrives late. Then, project implementers have to adapt original actions to what farmers already made. This was the main reason why farmers did not leave their transition cropland area totally free from chemical inputs. Also, mistrust between farmers and public administration, but even among themselves is an important obstacle to overcome, though some progress was achieved by working in groups and through participative approaches.

7.2. Future research lines

The selected research field shows great potential for future studies as shown in the growth of bibliographic resources dedicated to analyze sustainability practical applications. Facing the obtained results, it is considered that the ability of adapting to changing environments in a method to assess sustainability is required.

The main research line to continue with the research proposal here described is to find ways to test the potential of the SALT to trigger a transition towards sustainable agriculture. I consider that the most suitable method to validate results is to conduct a participatory workshop to share, contrast and evaluate the assessment results with farmers. This would be more congruent to the approach here advocated based in an agroecosystem perspective, participation, resilience and technology appropriation linked and adapted to the peculiarities of local contexts.

In future research farmers will co-decide the changes in the indicators set according to what is relevant for them. The SALT will then show its true potential through assessing change and and visualizing results in a dynamic way.

Overall, the SALT methodology proved to be suitable for assessing agroecosystems sustainability at local level. Potentially, the SALT can be up or downscaled and applied in different contexts. This can also be verified in future research. It would also be interesting to carry out chemical soil analysis to get tangible data on how actions made really impacted the soils composition and biological activities enabling to deepen the analysis and to assess its effects even at early stages.

Other research lines to be explored include incorporating climate change variables and scenarios, energy consumption analysis, microelements monitoring and cross-case studies.

7.3. Closing remarks

By contrasting results with agroecology and sustainability principles, it was found that their inclusion favors achieving success. Positive outcomes can be expected from applying sustainability guidelines and these are not limited to improving the environment, which already has importance, but actual economic and social benefits are possible. The focus must be placed in technologies and methods that can be locally applied while promoting natural diversity and social integration.

The implementation of the SALT contributes to strengthening the operational capacity of the sustainability approach by adapting to local contexts and needs, generating simple and applicable results and, stimulating decision-making processes influencing them to impact policies and projects. This is important for sustainable agriculture to be recognized as a necessity for peoples around the world. More specifically, the project "Organic farming promotion and development for grain producers in the state of Jalisco" is considered a key action for achieving rural sustainability at regional and national scale. The whole exercise helps providing profitable alternatives for maize farmers, which is mandatory against the rural backdrop in Mexico. The importance of this fact is highlighted in the current scenario that prevails in the country where the complex social, economic and political problems that have occurred – especially over the past 15 years –, have equally damaged the social fabric, the role of public institutions and the environment.

Although a trend towards more sustainable cropping methods was already observed in the region, the positive social and environmental performance of the alternative system pointed out by the assessment tool – mainly due to participative methods, organic and on-farm inputs and soil conservation practices – would have been less significant without the influence of a regional project. In economic terms this is less evident since costs were already lower in the alternative than in the conventional system, but the cost-benefit ratio did improve due to slightly higher yields and lower costs.

Sustainability is a concept in constant evolution. Therefore, sustainability assessment tools should be designed to adapt to constant changes in application and interpretation. Evidently, there is still much to do in this field. Here, only one of many ways to provide more practical outputs is explored. It is not desirable to simplify or uniform the sustainability approach but to make it applicable to generate clear results to achieve progress towards sustainable agriculture.

APPENDICES

APPENDIX A. STANDARDS FOR NORMALIZING INDICATORS

	Value / Indicator	*Source*	*100*	*75*	*50*	*25*	*0*
1	Participation in decission making (DM)	Interview	Full active participation with voice and vote in all group decisions	Participation with voice and vote in most group decisions	Participates with voice but no vote in final group decisions	Participates in small group decisions	DM is driven individually
2	Organized farmers	Interview	Actively involved in farmer's organization with voice and vote in horizontal DM	Involved in farmer's organization with voice in DM	Involved in farmer's organization with hierarchical DM	Part of an Ejido or union	Not organized
3	Level of commitment	Interview	Very concerned about environmental / social issues related with farm management as part of a whole and accounting for them in DM	Concerned with some environmental / social issues related with farm management especially of other farmers related	Aware that environmental and social issues are related with farm management; considers that farmers are somehow related	Aware about other farmers and how they manage their land considering that they have some influence over each other	Concerned only on managing his/her farm considering it as an independent unit
4	External input dependence	Interview / Field observation	0 to 20% of external inputs	20 to 40% of external inputs	40 to 60% of external inputs	60 to 80% of external inputs	80 to 100% of external inputs
5	Trained farmers	Interview/ Field observation	Is actively involved in farmer-to-farmer training	Participates and attends all training sessions	Attends to training from the government and input companies	Has attended to training from the government and input companies in the past	Usually does not attend to training sessions
6	Policies adequacy	Metadata	There is a sound institutional framework with local policies to strengthen transition towards sustainable agriculture	There are specific regional projects that can accommodate sustainable agriculture activities	There are some public policies that support punctual sustainable agriculture activities	There are national guidelines for sustainable agriculture hard to translate to local contexts	There is a discursive interest on sustainable agriculture but no practical ways to guide actions
7	Level of trust in public institutions	Interview/ metadata	Farmers trust public institutions in general	Farmers trust specific public institutions	Farmers trust specific persons from public institutions	Farmers distrust some public institutions	Farmers distrust all public institutions
8	Reliance on subsidies	Interview	Farmers are committed to sustainable agriculture regardless subsidies	Farmers would like subsidies but their activities towards sustainable agriculture do not depend on them	Farmers require support to continue carrying sustainable agriculture activities	Farmers demand more subsidies for engaging in sustainable agriculture	Farmers rely on subsidies to consider more sustainable alternatives

9	Adoption of new practices / technologies	Interview/ Field observation	Full incorporation of soil conservation practices, diversified crops, crop rotation and organic management	Soil partially covered and enriched; mixed cropping or crop rotation; organic management > 70%	Soil conservation is accounted; grows more than one crop; substitutes chemical inputs > 50%	Controls erosion processes; incorporates organic inputs; avoids class II-I chemical inputs	Incorporates compost or other non-conventional practices if provided by the government
10	Yield	Interview/ Field observation	Higher value=100; Other= % on the value				
11	Benefit/cost	Interview/ field/ metadata	Higher value=100; Other= % on the value				
12	Costs	Interview/ field/ metadata	Lower than medium costs in 20%	Lower than medium costs in 10%	Equal to medium costs (1 058,00 USD per ha)	Higher than medium costs in 10%	Higher than medium costs in 20%
13	Chemical input*	Interview/ Field observation/ metadata	No chemical inputs are used	Punctual use of class IV chemical inputs with main use of organic inputs	Class III-IV chemical inputs incorporating sustainable agriculture techniques	Reduction of class I-II chemical inputs and full chemical fertilization	Chemical inputs of any class are applied as needed
14	Erosion	Field observation	No erosion signs	Surface shows some laminar erosion	Evident signs of laminar erosion and some rills	Evident erosion rills and some gullies	Erosion with evident gullies
15	Vegetal cover*	Field observation/ metadata	Green manure in all cropping surface and organic inputs for weed management	Weeds are removed but all residues are incorporated to the soil with mainly organic inputs	Weeds are removed and partially incorporated; class III-IV herbicides are applied with some organic inputs	Weeds are completely removed or burned and class II-III herbicides are applied	Weeds are removed and burned; class I-II herbicides are applied
16	Crop rotation	Interview/ Field observation	Rotates every year with one year of rest for soil recovery	Rotates every year with a few months of rest for soil recovery	Rotates every 2 or 3 years	Rotates eventually	No crop rotation
17	Surrounding natural biodiversity	Field observation	Surrounded by natural vegetation by more than 50% and existence of conservation corridors	Surrounded by natural vegetation in 30 to 50% and buffer strips in roads	Surrounded by natural vegetation in at least one side	Surrounded by different crops and wastelands	Surrounded by the same monocrop and wastelands
18	Number of species grown	Interview/ Field observation	Highly diversified mixed cropping	Low diversified mixed cropping	2 or 3 species grown	Monocrop and some species for self consumption	Monocrop only

*Chemical inputs are classified according to the World Health Organization hazard standards (WHO 2009).

Appendix B. Benefit-cost analysis

Cost-Benefit ratio 2015 (per Ha)

Maize production costs (per Ha) by adopted system 2015

Production system		**Alternative**			**Conventional**		
Activity		*Units*	*Price (MXN)*	*Price (USD)**	*Units*	*Price (MXN)*	*Price (USD)**
Land preparation	Tillage	1,00	700,00	41,18	2,00	1400,00	82,35
	Plough	1,00	600,00	35,29	1,00	1200,00	70,59
Seeding	Seed	75000,00	2150,00	126,47	75000,00	3150,00	185,29
	Precision seeding	1,00	400,00	23,53	1,00	700,00	41,18
Organic inputs	Compost (Ton)	1,5	1800,00	105,88			
	Microorganisms (dose)	6	600,00	35,29			
Fertilizer	Triple (Kg)	180,00	1080,00	63,53			
	Urea (Kg)	250,00	1400,00	82,35	400,00	2800,00	164,71
	Ducor (Kg)				300,00	2100,00	123,53
	Foliar (l)				1,00	500,00	29,41
Herbicide	Integrity (l)				1,50	1275,00	75,00
	Convey (l)	2,00	1760,00	103,53	1,00	880,00	51,76
	Atrazine (Kg)	1,00	175,00	10,29	1,00	175,00	10,29
	Aplication	1 wage	150,00	8,82	1 wage	150,00	8,82
Insecticide	Cypermethrin (l)	1,00	136,00	8,00			
	Lambdacialotrine (l)				0,25	32,50	1,91
	Chlorpyrifos (l)				1,00	180,00	10,59
	Application	1 wage	150,00	8,82	1 tractor	500,00	29,41
Threshing and transport	Threshing	1 wage	1200,00	70,59	1 wage	1200,00	70,59
	Freight	10,00	1300,00	76,47	8,00	1040,00	61,18
	Insurance	1,00	1100,00	64,71	1,00	1100,00	64,71
	TOTAL COSTS		14701,00	864,76		18382,50	1081,32

	Alternative		*Conventional*	
	(MXN)	(USD)	(MXN)	(USD)
Returns (Ton per Ha)	10,00		8,00	
Price per Ton	3500,00	205,88	3500,00	205,88
Total income	35000,00	2058,82	28000,00	1647,06
Total costs	14701,00	864,76	18382,50	1081,32
Income - Costs	20299,00	1194,06	9617,50	565,74
Benefit-cost ratio	2,38		1,52	

Costs expressed in USD where computed in MXN and correspond to 2015 prices in Mexico. Exchange rate: 1 USD = 17 MXN.

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