Resilience Assessment of Social-Ecological Systems in MENA Region: An Application of Tri-Capital Framework in Jordan, Tunisia & Morocco

MASTER THESIS

Maroua Afi

Agricultural Economics Engineering
Rural Development and Project Management

Tunisia

Madrid, 2018

AGRIS Mundus
Sustainable Development in Agriculture
Master of Science

UNIVERSITY COLLEGE CORK
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Resumen

Las tierras secas de las regiones MENA tienen diversos sistemas de producción agrícola que están integrados en sistemas sociales y ecológicos (SES) más globales. Para satisfacer las necesidades de la población, los esquemas de intensificación de la producción de alimentos en esta área generan costos sociales y ambientales debido a la vulnerabilidad de estos sistemas, y este orienta la investigación actual para promover la intensificación sostenible. Teniendo en cuenta la complejidad, vulnerabilidad y diversidad de los sistemas, mediante este trabajo, proponemos, en un primer nivel, una tipología de los perfiles de resiliencia de los sistemas socio-ecológicos en la región MENA, utilizando un conjunto explicativo de variables que definen los medios de vida rurales y los sistemas agrícolas por un lado, así como los determinantes de la resiliencia; capacidad de almacenamiento intermedio, auto-organización y capacidad de aprendizaje, por otro lado. En consecuencia, procedemos a medir y escalar el indicador de precariedad (Pr), que representa la distancia hasta el punto de colapso, para los diferentes sistemas socio-ecológicos resultantes de la tipología utilizando el método del Marco Tri-Capital que consiste en desarrollar y puntuar indicadores compuestos. Por tri-capital, nos relacionamos con el capital económico (EC), el capital social (SC) y el capital natural (NC). Para el análisis de datos; evaluación de factores, tipología e indicadores, utilizamos SPSS (Paquete estadístico para las ciencias sociales). El estudio abarca tres países: Jordania, Túnez y Marruecos; donde los datos fueron recolectados por ICARDA en 2014 dentro del "Consortium Research Program on Livestock" (CRP1.1). Los resultados destacaron la diversidad y las diferencias, o similitudes, entre los sistemas de producción en el mismo país y entre países. Los valores del indicador Pr comienzan de cero a 5.3; mientras que los cabezas de familia con Pr entre cero y 3.50 se consideran débilmente resistentes. Por lo tanto, si el indicador de Pr varía entre 3.50 y 4.20, los propietarios se consideran moderadamente flexibles y si el puntaje está entre 4.20 y 5.3, son muy flexibles. Se revela que una resiliencia moderada es engendrada por contribuciones equilibradas de capital natural, económico y social que destaca la importancia de un enfoque holístico para promover la intensificación sostenible y hacer políticas de desarrollo rural.

Palabras clave: *Intensificación sostenible; Sistemas socio-ecológicos; Resistencia; Precariedad; Marco Tri-Capital*

Abstract

Drylands of MENA regions have diverse agricultural production systems that are embedded under more global social-ecological systems (SESs). In order to meet population needs, food production intensification schemes in this area engender social and environmental costs because of the vulnerability of these systems, which orients current research to promoting sustainable intensification. Considering the complexity, vulnerability and diversity of systems, by this work, we propose, at a first level, a typology of social-ecological systems' resilience profiles in MENA region, using an explanatory set of variables defining rural livelihoods and agricultural systems on one hand, as well as resilience determinants; buffer capacity, self-organization and capacity for learning, on the other hand. Consequently, we proceed to measure and scale precariousness (Pr) indicator, which represents the distance to collapse point, for the different social-ecological systems resulting from the typology using the Tri-capital Framework method which consists of developing and scoring composite indicators. By tri-capital, we relate to economic capital (EC), social capital (SC) and natural capital (NC). For data analysis; factor analysis, typology and indicators scoring, we used SPSS (Statistical Package for the Social Sciences). The study covers three countries: Jordan, Tunisia and Morocco; where data were collected by ICARDA in 2014 within Consortium Research Program on Livestock (CRP1.1). The results highlighted the diversity of and differences, or similarities, between production systems in the same country and between countries. The Pr indicator values start from zero to 5.3; while householders with Pr between zero and 3.50 are considered weakly resilient. Therefore, if the Pr indictor is ranged between 3.50 and 4.20, householders are considered moderately resilient and if the score is between 4.20 and 5.28, they are strongly resilient. It is revealed that a moderate resilience is engendered by balanced contributions of natural, economic and social capital which highlights the importance of a holistic approach in promoting sustainable intensification and making rural development policies.

Keywords: *Sustainable intensification; Social-ecological systems; Resilience; Precariousness; Tri-capital framework*

Introduction

The world population is predicted to achieve 9 billion by 2050 (United Nations, 2008) which requires an increase up to 100% in food production (World Bank, 2008). Intensification of agricultural production was endorsed as a predominant alternative in face of this challenge (Smith, 2012; Tilman et al., 2011). However, the greater challenge doesn't only consist of production intensification, as an urgent need to meet with population growth, but also of the environmental costs that might be engendered by this intensification. Furthermore, Robinson et al. revealed that there is a continuous concern about large numbers of people not benefiting from the advancement neither the introduced technologies, instead, they are paying social costs (2015).

Therefore, recent research focuses are directed towards "sustainable intensification" (Robinson et al., 2015) which can be defined as "producing more outputs with more efficient use of all inputs – on a durable basis – while reducing environmental damage and building resilience, natural capital and the flow of environmental services" (The Montpellier Panel, 2013). The paradigm of sustainable intensification highlights that research and intervention related to agricultural technologies and practices must always be interconnected with the social context such as rural economies, social and cultural impacts of agricultural changes, as well as the main concern of systems vulnerability (Garnette et al., 2013). In fact, the concept of vulnerability is a useful analytical tool to explore all dimensions -economic, social and environmental- for a sustainable intensification of agriculture in dry lands (Robinsonetal., 2015). Recently, vulnerability theory has evolved and has been, explicitly, linked to resilience thinking (Adger, 2006). "Current sustainable intensification discourse does not devote sufficient analytical attention and rigor to social and economic issues" (Robinson et al., 2015). Lately, Van Ginkel et al., (2013), offered an integrated systems research that goes beyond sustainable intensification emphasizing the people's urgent need to learn how to manage risks rather than intensifying production. Considering the urgent need to increase production in dry lands in regards to the complexity, vulnerability and diversity of systems, The CGIAR Research Program (CRP) on Integrated Agricultural Production Systems for Improved Food Security and Livelihoods on Dry Areas, promotes a holistic research approach which analyzes the interactions between all systems components that interfere in improving or limiting agricultural productivity. The CGIAR Research Program actually aims to identify appropriate development interventions by relying on relevant research findings. It examines social, financial, technical, and environmental contexts in drylands in order to provide a comprehensive analysis of dryland development challenges and to formulate appropriate technologies, practices and policies in response to these challenges.Actions sites for projects setting were installed along drylands including Middle East and North Africa (MENA). In MENA regions, projects were coordinated by the CGIAR International Center for Agricultural Research in Dry Areas (ICARDA) who collected the baseline data in 2014. Regarding the availability and quality of data, we consider the three countries of Jordan, Tunisia and Morocco for our study who actually aims to classify different production systems, functioning within more global social-ecological systems, that are mostly-prominent in MENA countries and to assess the resilience of each identified system by means of application of the Tri-capital framework method.

1. Social-ecological systems resilience

The inter-connection and strong link between agriculture and ecology explains the interest in the application of resilience concept, it is always a major aim to produce food and maintain ecosystem services'. In this regard, Darnhofer et al. (2010) examine farming as part of a set of systems across spatial scales, from farm to global, encompassing agro-ecological, economic and political-social domains. Because it is not only about the environment, it is also necessary to consider social and economic dimensions (Barbier, 1989), and more than a focus on production and efficiency, farm sustainability is achieved through adaptability, learning and change (Darnhofer et al., 2010); research tasks characterizing and assessing the resilience of socio-ecological systems became a major challenge.

1.1. Social-ecological systems

Resilience early insights' highlighted the need to focus on coupled social-ecological systems (SESs) based on holistic approaches in order to understand the complex functioning of these systems (figure 1). It is important to understand biology in great detail, however it is not enough, it is also crucial to develop an understanding of the dynamics of the markets, drivers of resources use and cultural attachments. On the other hand, it is not enough to only count on a detailed economic analysis if it doesn't include details on biological limits of production. Thus, understanding the functioning of the system as a whole permits a better understanding of its behavior, vulnerability and adaptive capacity to shocks. All humanly-used resources are embedded in social-ecological systems (Ostrom, 2009) ,"SESs are composed of multiple subsystems and internal variables within these subsystems at multiple levels analogous to organisms composed of organs, organs of tissues, tissues of cells, cells of proteins, etc." (Pennisi, 2003). A core challenge in identifying the differences between a sustainable SES and an unsustainable one is the diagnosis and analyses of relationships among multiple levels of these complex systems (Berkes et al., 1998), which reveals that complexity is rather dissected than eliminated for a better understanding of the system functioning. In this regard, for the following, a social-ecological system consists of a "human subsystem" and a "natural subsystem".

1.2. Diversity of social-ecological systems

Social-ecological systems are various and heterogeneous, not only in regards to the complexity and divergence of interactions between subsystems, but also because of the differences within those subsystems: "Heterogeneity across natural systems reflects natural land cover change, disturbance, and anthropogenic land use change; likewise, in human subsystems, heterogeneity exists as a function of variation in individuals, policy, political and social philosophy, socioeconomic incentives, institution legacies, and population demographics and growth rates" (Quinn & Wood, 2017). Individual and communal preferences for environment types are guided by resources availability and institutional context in addition to agricultural practices that are mostly related to market trades alimentary needs, thus, social-ecological systems are diverse, on the three scales: national, regional and even local, which requires a closer look to each type of SES and a deeper analysis of its dynamics. Hence, a typology of SES in our three study countries, is relevant in order to generate more accurate representation of farm types and resilience profiles.

1.3. Resilience determinants

Resilience was first defined as "a measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationship between populations or state variables" according to Holling (1973) who applied resilience concept to ecological system. Mackinnon and Derickson (2012) claimed that due to the expansion and omnipresence of social, economic and ecological crisis, resilience application was extended to the public domain. Mainly, resilience helps to understand the *factors* that enable *actors* to shield their livelihoods from adverse outcomes of change (Speranza, 2014). It also refers to the capacity of individuals, social groups or SES to adapt to stress and turbulences, to self-organize and to learn in order to sustain basic structures and functions or in order to improve them (Berkes and Folke, 1998; Carpenter et al., 2001; Walker et al., 2002; Berkes et al., 2003; Folke, 2006; Adger, 2003, 2006). Therefore, resilience is also linked to human agency and to social structures within system-oriented approaches (Bohle et al., 2009; Obrist et al., 2010) and three major attributes, which are composed of several proxy indicators (Carpenter et al., 2001; Milestad and Darnhofer, 2003; Milestad, 2003), can be identified; buffer capacity, self-organization and capacity for learning (Speranza et al., 2014). According to Speranza, resilience is maintained when buffer capacity exists and is not weakening, self-organization exists and is endorsed and learning occurs (2014).

Buffer capacity

Buffer capacity is defined as the amount of disturbance a system can endure and still maintain the same structure, function and feedbacks (Carpenter et al., 2001; Resilience Alliance, 2010). Livelihood capitals (assets) and their dynamics depict the buffer capacity (Speranza et al., 2014), thus, according to Speranza (2013), the adaptive capacity of livelihoods, or buffer capacity, is defined as the capacity to cushion change and to use the emerging opportunities to achieve better livelihood outcomes such as reduced poverty". From a livelihood and actors' perspective, buffer capacity labels the resources that people acquire (assets) and the strategies they adopt to generate a living (activities), however, it does not only focus on financial and economic capital but also draws focus on social assets, such as networks and institution, as well as human assets related to household educational and experience levels. Hence, for the present work, buffer capacity, as a resilience determinant, relies on a livelihood approach. A livelihood approach can help improve the understanding of people's adaptive capacities and how to reduce poverty as it puts "people's livelihood concerns" (Ashley, 2000). Speranza et al., (2014) resumed the buffer capacity in two main indicators: endowments and entitlements. Endowments stand for resources owned by an actor, and they are generally related to livelihood assets; either human assets (education, experience, health), financial assets (income and savings), physical assets (machinery and technology), social assets (co-operatives and networks) and natural assets related to soil quality and land productivity. Entitlements, on the other hand, refer to actors' access to resources; entitlements are "the set of alternative commodity bundles that a person can command in a society using the totality of rights and opportunities that he or she faces" (Sen, 1984); an entitlement set is a person goods and services that he or she can acquire by converting the endowments (Devereux, 2001). Ultimately, in a social-ecological system, livelihood buffer capacity is determined by individual access to and use of resources. Furthermore, it also depends on livelihood strategies to improve and expand their capabilities (Speranza et al., 2014).

Self-organization

In social systems, self-organization can be used in two ways; one is based on the general systemic sense and the other is based on an autonomous sense (Speranza et al., 2014). The general self-organization in social systems is related to society norms and values, rules and organizations that contribute to a society creation and define it, a general self-organization is also the diverged, and sometimes conflicted, dialogue between social structures (top-down processes) and human actions (bottom-up processes) excluding any exterior regulations or constraints interference to the system (Di Marzo Serugendo et al., 2004).

While an autonomous self-organization highlights the independency of individuals (actors) in determining their own rules (Speranza et al., 2014) which translates a certain level of self-reliance and sovereignty in social self-organization. In this regard, self-organization of farming systems translates the ability of a group of farmers to interact with the social, economic and institutional environment by forming flexible networks, locally and on larger scales (Milestad, 2003). Accordingly, Obrist et al., (2010) argued that, related to the resilience context, self-organization determines the ability of human agency, through adaptive capacities and social interactions, to shape social resilience. In a social-ecological system, self-organization is indicated by existing norms and rules (Cabell and Oelofse, 2012); social rules and organizations can either enhance or limit actors' adaptive capacities which reveals the important role they play in building resilience (Speranza et al., 2014). According to the livelihood resilience measurement framework proposed by Speranza et al, (2014), self-organization is determined by institutions hindering or fostering livelihood and how actors' practices can generate Institutions that are adaptive to change and resilient to shocks. Furthermore, cooperation and networks are also important bases for self-organization and translate interactions between actors within social-ecological systems that contribute to forming own rules and values (institutions), building trust and facilitate access to information, innovation and capital (Ifejika Speranza, 2010).

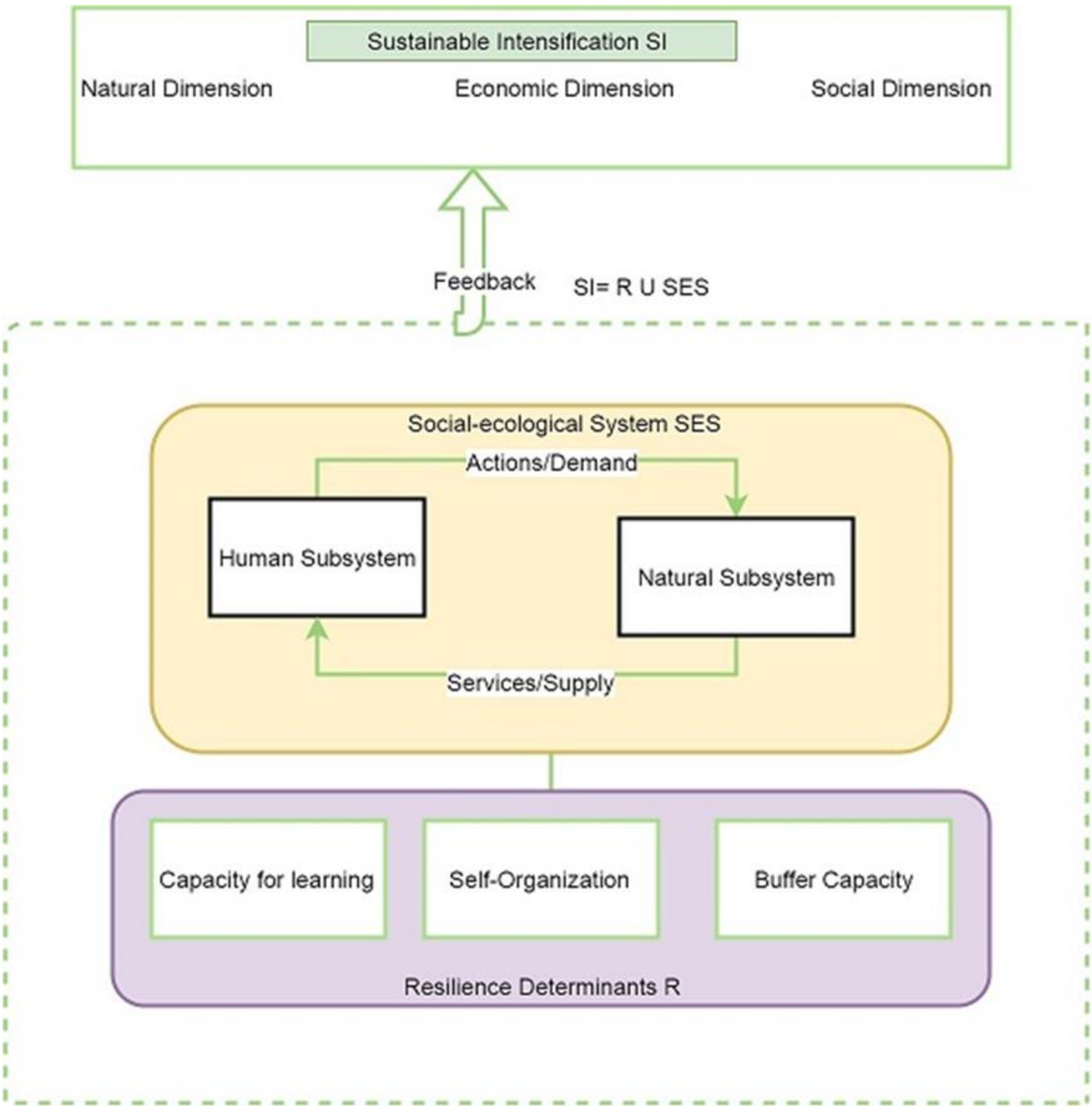
Capacity for learning

The capacity for learning is an important determinant of social-ecological systems resilience, it emphasizes the adaptive management and the ability to learn from previous experiences to improve current management; which reveals that a resilient social- ecological system is a learning system and it has a memory (Speranza et al., 2014). Learning is defined as the acquisition of knowledge or skills and learning ability, according to Speranza et al., either at an individual livelihood level or a system level is crucial for building resilience (2014). Individual and societal capacity for learning have been well-valuated by organizational learning literature. In 1978, Argyris et al., defined learning as being not just about enlarging knowledge or acquiring skills, but most importantly, is about converting the knowledge into actions and the skills into deeds. In this vain, Kim (1993) claims that "learning encompasses two meanings: (1) the acquisition of skill or know-how, which implies the physical ability to produce some action, and (2) the acquisition of know-why, which implies the ability to articulate a conceptual understanding of an experience", that is, connecting "thought and action". The previous statement reveals that learning from the previous activities and associating the past to the present for better future is an important factor for building social-ecological systems resilience, mainly based on interactions between human and natural subsystems. Speranza et al., (2014) studied capacity for learning at individual/ household level from one side and system/group level from another side, as learning is not an automatic process and several factors interfere in realizing it. They focused on measuring the knowledge of threats and opportunities, openness and interactions, knowledge transferability as well as ability of monitoring and impact assessment. For this current work, we, thus, will develop an analogy to Speranza et al., (2014) framework that fits with the research context.

1.4. Resilience of social-ecological systems feedback for sustainable intensification

The concept of resilience is a useful analytical tool to explore sustainable intensification through the three dimensions of sustainability: economic, social and environmental in relation to agricultural intensification (figure 1). Assessment and scaling resilience of social-ecological systems entails an understanding of the system vulnerability against intensification or its potential to endure an intensification. As previous studies assumed the existence of a vulnerability threshold, below which intensification cannot occur, and thus communities might require either vulnerability-reducing or intensification-promoting (Robinson et al., 2015). Resilience is largely applied in human-nature interactions, mediating the linkage between socio-economic, socio-cultural, environmental and political factors, which aims to analyze system's vulnerability and enhance its adaptive capacity for a sustainable intensification. Nevertheless, an empirical assessment of social-ecological systems resilience is challenging (Linstdter et al., 2016); on one side, social-ecological systems complexity entails integrating knowledge, theories and approaches from several disciplines (Ostrom 2009*,* Schlüter et al. 2014) and thus it is crucial to use a multidisciplinary resilient assessment by referring to broad sets of indicators (Quinlan et al. 2016). Yet, such an assessment is still, so far, established from perspective of one discipline and oversimplifies either the ecological or the social subsystem (Schlüter et al. 2014). From another side, defining a social-ecological system and its subsystems as well as specifying its interdependencies requires more understanding on how cross-scale interactions affect the coupling between subsystems (Allen et al., 2014) and the SES's resilience. In this regard, resilience of social-ecological systems assessment will result on a feedback that could be useful for sustainable intensification appropriation of technical and/or policy interventions within such context. It demonstrates the challenges of each system and "the need for action" sites. Ultimately, resilience needs to be assessed against an appropriate baseline such as the system's desirable state (Liu, 2014) or undesirable, and in this regard, the following part, focuses on presenting tri-capital resilience measurement framework that allows to measure the distance to the collapse point or a transformative state after the occurrence of disturbance.

Figure 1: Conceptualization of SES resilience feedback on sustainable intensification



Source: own elaboration

2. Tri-capital framework to assess social-ecological systems' resilience

Adger (2000) defined resilience in ecological and social systems as being "The ability of communities to withstand external shocks to their social infrastructure". He added, in the same context, the following description in 2003 "The ability to persist (i.e., to absorb shocks and stresses and still maintain the functioning of society and the integrity of ecological systems) and the ability to adapt to change, unforeseen circumstances, and risks". Thus, Edgar focuses on the dependence of communities on ecosystems in creating their livelihoods and browsing their economic activities. Wilson (2010) thinks that it is useful to define community resilience as an "outcome" as well as a "process". On the first hand, when linked to improved adaptive capacity, it is considered an "outcome". However, on the other hand, when linked to changes, community knowledge and their willingness to take control of their rural development pathway, it is a "process". According to Scott

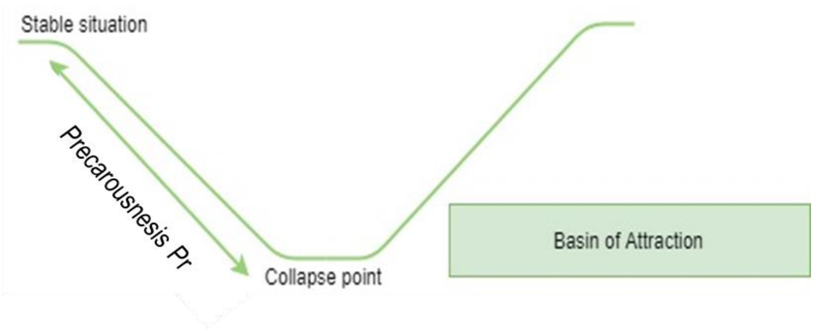
(2013) literature have actually revealed two contrasting approaches to resilience, "the evolutionary approach" and "the equilibrium approach".

Starting with the equilibrium approach, it is very reliable in disaster management and strategic responses to natural calamities, terrorist attempts and disease outbreaks (Barr and Devine-Wright, 2012). An equilibrium approach of resilience highlights the ability to "bounce-back" to the pre-shock situation; it emphasizes the aptitude of an economy to maintain a pre-existing state or return to the ancient state of growth in the presence of an exogenous disrupt.

The evolutionary resilience approach, on the other side, contradictory to the equilibrium one, rejects the theory of "bounce back" and return to the normal state. It relies on the principle of ongoing evolutionary change process highlighting an adaptive conduct to the new current state. A "bounce forward" emphasizes the creation of new pathways and enable transformation in order to move forward and survive the disturbance. Contrary to the equilibrium resilience approach that implements a short-term response to shocks, the evolutionary resilience presents a long-term response and emphasizes a capacity of adaptation and adaptability.

Social-ecological systems' resilience emphasizes the persistence of ecosystems with their allied social institutions (actors) (Anderies et al., 2004), it consists of the system's aptitude to apply necessary changes and reorganizations in order to absorb disturbance and maintain functionality(Jarzebski et al., 2016). Within SES studies, resilience is described by the stability landscape concept entailing "basins of attraction" that represent other favorable and stable conditions, as well as alternative less desirable states (Walker et al. 2004; Scheffer et al. 2012). A basin of attraction is defined by Jarzebski et al. (2016) as "an alternative state adjacent to the existing system state and is separated by the basin's edges, representing thresholds of state transformation". Within a basin of attraction, resilience is determined by three features: precariousness, latitude and resistance (walker et al., 2004). Precariousness, of a system within a basin of attraction, is the distance from the current state of this system to another state. Latitude is the maximum amount of change a system can endure before transformation, it is the width of the basin; and resistance measures how difficult it is to modify the system's state (Jarzebski et al., 2016).

Figure 2: Basin of attraction of SESs



Source: adapted from literature Jarzebski et al. (2014) and Walker et al., (2004)

Individual and collective human agency emphasizes the community capacities to endure or adapt to continuous change in nature and society (Magis, 2010; Jarzebski et al., 2016). Wilson (2010,2012) refers to the capitalization approach, including the human domain as a key driver and a major agent to manage community "transition" in a changing environment (Jarzebski et al., 2016). The interactions and desired balance between social, economic and natural capitals are the main determinants for resilience levels; weak, moderate and strong, as highlighted and developed by Wilson (2013) and known as community resilience framework. Jarzebski et al., stated that "consideration of mutual interactions and convertibility of the three forms of capital, economic, natural and socio-cultural, is necessary within social-ecological system analysis" based on Berkes and Folke (1998) and on the demonstration developed by Abel et al. (2006) that introduced the capital framework as an operating dynamic assessment tool representative for social-ecological systems resilience.

Economic Capital

Economic capital (EC) is divided into two different forms of capitals, a produced capital (or physical (PC)) and financial capital (FC) (OECD, 2013). Produced capital includes all types of physical assets such as buildings, infrastructure, transportation and mechanization; in some cases, it can also include knowledge assets such as computer software. On another hand, financial capital refers to all monetary assets including deposits, credits, funds and income. The accumulation of physical and financial capitals is a determinant of household economic stability and security (Jarzebski et al., 2016). Economic capital management, investments and allocation must also be considered in the assessment of community resilience, otherwise, only wealthy households would be opted resilient because of funds availability.

Natural capital

Natural capital (NC) incorporates environmental assets that provide several goods and services; soil, water, food, minerals and other energy resources, biodiversity and natural vegetation (OECD ,2013). The resources that constitute natural capital vary widely, ranging from intangible public goods such as the atmosphere and biodiversity to divisible assets used directly for production (trees, land, etc.). Individually or collectively, community members have access to these resources (Jarzebski et al., 2016) and utilize them to generate basic and complex products that are essential to maintain human life. Natural capital use translates human preferences in regards to particular environments and socioeconomic settings (Harte, 1995), meanwhile, it should be preserved in order to keep ongoing development processes and not limit further ones (Ekins et al., 2003).

Social capital

Social capital (SC) refers to "the social norms, trust, and values that foster cooperation within or among different groups in society" (OECD, 2013). Social capital can be subdivided into human and cognitive capacities of a society. Human capital (HC) relates to age range, educational level and experience of household, individually and collectively, which reflects the significance of the active population role within a social-ecological system. Cognitive capital (CC), on another hand, determines the household, at first level, and the community, at a second level, aptitude to learn and to evolve within structured social and political environment. It expresses a community's capacity to adapt to and modify the social–ecological system (Berkes and Folke, 1998). Social form of capital outline resilience and adaptation capacities of social-ecological systems to risk and change (Berkes and Folke 1998; Ifejika Speranza et al., 2014; Wilson, 2010). Hence, we consider social capital in its two forms of human and cognitive capital.

To summarize, tri-capital resilience measurement framework is a representative assessment tool of social-ecological resilience, as it allows the understanding of convertibility and interactions between different capitals. Capitalization also permits the quantification of resilience, which is an innovative analysis framework, allowing the determination of resilience level and the state of households within their social-ecological systems. The following section is built on literature contributions and it gives more information on data collection, study cases presentation and tools and methods used to respond to the objective of this work in assessing SES resilience.

3. Objective and Methodology

Drylands are diverse and have different climatic, topographic and environmental characteristics, they also vary economically, socially and culturally. In despite of these differences, dry regions face one common challenge: system vulnerability against food insecurity and climate change. As already mentioned, CGIAR program has various action sites that were selected to represent rural livelihood across 3 billion ha of dry areas in five geographical regions: West Africa Sahel and the Dry Savannas; North Africa and West Asia; East and Southern Africa; Central Asia; and South Asia. Baseline surveys were conducted to characterize agricultural production systems and assess their vulnerability. The surveys provide detailed description of current farming systems and land use; they define local rural livelihood and different income sources. They also deliver information about the level of technology adopted in crop and livestock production, perceptions over policies and institutions; as well as the constraints encountered by farmers. In addition, more emphasis is placed on understating gender role in dryland agricultural production systems. Based on the collected data, our study focuses on the characterization of different agricultural production systems resilience profiles and resilience assessment in three countries of Middle East and North Africa region: Jordan, Morocco and Tunisia using the tri-capital framework method. Our objective is to adapt an innovative resilience measurement approach and test its applicability in a different context. Considering the heterogeneity and diversity of SESs, we start by applying a typology of different SES and their current resilience strategies, if it exists; using a set of variables that determine rural livelihoods and agricultural systems beside resilience determinants: buffer capacity; self-organization and capacity for learning. We later, proceed to assessing resilience of the different identified SESs by means of the tri-capital framework that, through capitalization and Pr calculation, allows resilience quantification. In this regard, based in the existing literature beside the existing data, the following section presents the study sites in the three MENA countries in addition to the analytical framework of data.

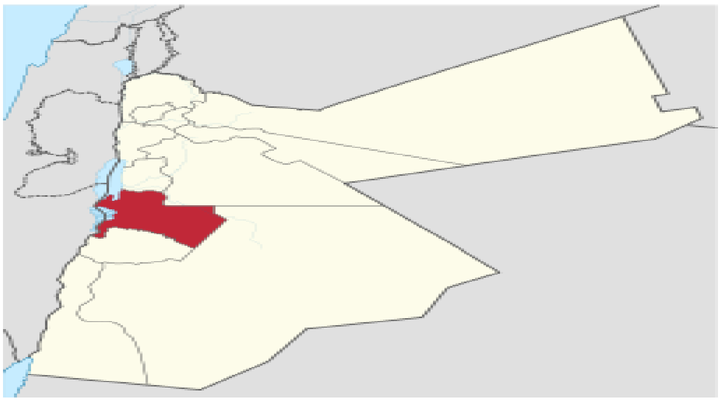
3.1. MENA region study cases: Jordan-Tunisia-Morocco

The main reasons that are behind the choice of these three countries are related to the relevance of their context, diversified socio-economic settings and varied natural which could make a certain representativeness to MENA region agricultural situation. Also, the data set of Jordan, Tunisia and Morocco are the most relevant regarding, sampling techniques and sample sizes beside the data quality.

Jordan

Karak Governorate, located 120 km south-west of Amman, the capital city of Jordan has an estimated human population of 249,100 with an area of 3495 km² and a population density of 71.3. The Karak Governorate is subdivided into 7 administrative units located in different agro-ecological zones, ranging from the rift valley in the west, highlands in the central region, and a semi-desert in the eastern and southeastern regions. The climate is characterized by hot dry season starting from April to October and a rainy wet season that starts from November and lasts until March. Average temperature varies between 4 during winter and 32°C during summer. Rain ranges between 200 and 350mm. The simple includes 468 households who were randomly selected.

Figure 3: location of Jordan-Al Karaak study area

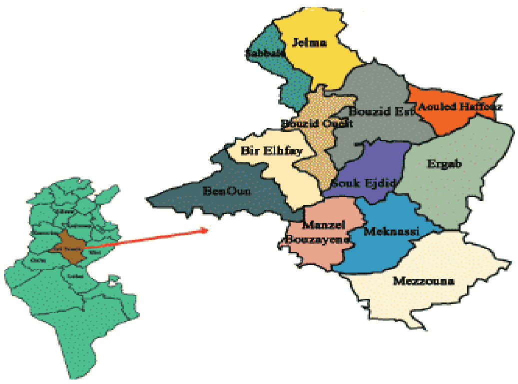


source: country report (ICARDA, 2015)

Tunisia

In Tunisia, five governorates were included in the CRP: Sidi Bouzid, Medenine, Gafsa and Gabes. For this study, only data collected at Sidi Bouzid site were used on the analysis. Sidi Bouzid governorate is located in Central Tunisia (figure 1). It covers an area of 7405 km^2 and it has an arid climate with an annual rainfall between 200 and 300 mm. The Governorate of Sidi Bouzid includes 12 districts, 10 municipalities, 111 sub-districts and 12 rural councils. Its population counts over 400 thousand inhabitants, 77% of this population is rural and their income is generated by agricultural activities. Furthermore, rate of poverty in the governorate is 40%.

Figure 4: Location and districts of Sidi Bouzid



Source: country report (ICARDA, 2015)

Data was collected in Jelma district, in the northwest of Sidi Bouzid. Jelma is known by the lack of water resources and the dominance of livestock production as well as the existence of collectively shared resources (grazing land, water...) which requires a collective action. The sample is of 250 households who were randomly selected according to representativeness criteria, 105 households are from Selta sub-district and they represent 17 communities while 145 households are from Zoghmar sub-district and they represent 34 communities. The average land size in Selta is 10.2 ha and it is of 6 ha in Zoghmar. Jelma district counts only 17 deep wells which translates the vulnerable hydric resources in the area.

Morocco

The Meknes-Saiss area covers an area of about 1694 km2 in the north of Morocco (Figure 4), with a rural population share of 20%. This action site has a semi-arid to sub-humid climate. The average annual precipitation is relatively high for a dryland area, ranging from 500 to 800 mm a. The rainfed mixed system is the dominant system, crops in this system are primarily rainfed. Common crops are wheat, chickpeas, lentils, faba bean and fodder crops. There are tree crops (olives and fruit trees) and grapes. Many farms are intensively capitalized with a high level of inputs, and farmers are very sensitive to market opportunities. There are a number of specialized dairy and poultry systems within this ecological zone. Major production constraints are poor access to quality land by increasing numbers of small farmers, soil erosion on slopes during rainstorms, and erosion by wind on light, over-cultivated, exposed soils.

Figure 5Location of Morocco study area

Source: country report (ICARDA, 2015)

Three representative locations of the main agricultural region where selected: Ain Jemaa, Sidi Slimane, and Bitit locations were selected. A multi-stage random sample technique was used. Villages were selected randomly using topographic maps. A subgroup of 28 villages is selected randomly, which represents 49% of total villages in the three locations. Distribution of the selected villages was as follow: 14 villages in Ain Jemaa from a total of 29; 10 villages for Sidi Slimane from a total of 20, and 4 villages from Bitit from a total of 8 villages. The total sample size is of 508 households.

3.2. Analytical Framework of data: Clustering analysis variables and methods

Cluster analysis objective is to identify homogenous groups of farmers that are differentiated upon the social-ecological system they are part of and their resilience patterns. It enables to pass through massive data and gain first order knowledge (Duda et al., 2000; Hastie et al., 2001). It divides data points into disjoint groups so that the data points who belong to the same cluster are similar whereas the data points who don't belong to the same clusters are dissimilar (Ding et al, 2014). K-means method is one of the most popular and most efficient clustering methods that uses prototypes to represent clusters by optimizing the squared error function (Hartigan & Wang, 1979; Lloyd, 1957; MacQueen, 1967).

Table 1 Number of variables used in the typology per category per country*

	Number of variables used in the typology per category and per country		
Categories of variables	Jordan	Tunisia	Morocco
Demographic characteristics (age, education, experience etc.)	3	2	3
Natural assets (land use, land size, resources etc.)	7	5	8
Physical assets (livestock, machinery etc.)	3	2	3
Financial assets (crops income, livestock income, off-farm income etc.)	3	5	4
Buffer capacity(access to credit, buffer capacity etc.)	4	2	4
Self-organization (extension etc.)	2	3	2
Capacity for learning (social participation and openness, etc.)	3	3	3
Total number of variables	25	22	27

Source: own elaboration *Please see appendix 1 for variables complete list

At a first place, high dimensional data are firstly-transformed into lower dimensions by referring to principal component analysis (PCA) (Jolliffe, 2002). The objective of PCA is to explain a large data set using a smaller number of uncorrelated variables, the new generated continuous variables data set, called "principal components", retains the maximum possible amount of information of the original data set (Frija et al., 2016). In fact, most of the variation in the data set is expounded in the first component while the second component is orthogonal and covers much of the remaining variation and so on (Keenan et al., 2012, Frija et al., 2016). Principal component method is still considered as one of the most efficient available methods for identifying relationships between different types of variables, outlining groups differences and detecting outlier observations within data set (Frija et al., 2016). Therefore, the principal components are used in K-means cluster analysis while the risk of correlated-variables is eliminated.

An explanatory list of variables was set up for the typology; the list includes variables that define rural livelihoods and agricultural systems. It also includes parameters that allow the characterization of resilience profiles through main resilience determinants: buffer capacity, self-organization and capacity for learning. The selected variables should vary slightly upon the relevant context of the country and available data; they are classified in different categories as represented in table 1. Demographic characteristics category includes variables such as household head age, family size, farming experience etc. The category of natural assets refers to land size and land use, water availability and soil quality. Physical assets category includes variables that detain information on livestock production: number of heads of cattle or small ruminants and also on mechanization availability and transportation means; financial assets category has more emphasis on detecting income sources and stating the contribution of each to rural livelihood. Resilience determinants focus more on assessing the household capacity to respond to risk and to adapt to transformation. Buffer capacity category variables diagnose the existence of reliable sources that guarantee access to credits in time of shortage, household members ability to contribute to farm work, land ownership status and season cropped area. Self-organization and capacity for learning categories emphasize more the openness of household to social network and research institutions and their interactions, as well as their willingness to evolve and learn.

3.3. Analytical Framework of data: Tri-capital resilience framework: variables and indicators to measure NC, EC and SC

This section provides an explanation of the approach we used to assess resilience through measuring and quantifying the three forms of capitals; it reveals the list of indicators identified to provide a snap shot of the current economic, social and natural state of the system. Based on previous knowledge of communities' situations and existing literature analysis, a set of indictors was identified and adapted to the contextual needs and data availability. The objective is to assess communities, in general, and specifically household ability to perform a sustainable intensification theme through measuring its resilience to shocks and its transformation capacities. The core basis of indicators choice is the previously cited resilience determinants used in the typology of social ecological systems resilience profiles. We acknowledge existing frameworks that identify indicators to analysis of dynamic human-environment interactions such as that of Ostrom (2009); and also indicators of community resilience building such as that of Berks and Ross (2013) and Jarzebski et al. (2016). For our study, we adjusted relevant indicators in the existing literature to sort out five to ten composite indicators for each of the three forms of capital. The indicators, cited in the following section, are either already existing in the literature or an own elaboration taking in consideration the existing data and adaptability of the approach to the context specificities.

Natural capital indicators

Natural capital indicators (table 2) shed the light on land availability and land use as land is a main livelihood source and food origin. Land description is highlighted by land's physical state (Ekins et al., 2003); according to soil fertility index in addition to physical size of land and share of cropped area compared to the total available land. Water availability is also incorporated in the description of natural capital. Natural capital indicates localization of rural livelihood and aptitude for operational sustainable intensification.

Table 2: Natural capital set of indictors

NC= (NC1+NC2+NC3+(NC4*NC5))/4
NC1 : physical size of land per person per household
NC2 : land ownership : share of owned area from total cultivated area
NC3 : Land use : share of season cropped area compared to the total available land
NC4 : physical state of soil: soil fertility index (if good or medium then 1, if not then 0)
NC5 : water availability : water quantity index (if good or medium then 1, if not then 0)

Economic capital indicators

Economic capital (Table 3) is subdivided into two categories: financial capital (FC) and physical capital (PC). Physical capital incorporates variables that describe livestock production regarding number of heads of cattle and small ruminants beside transportation and machinery while the financial capital has an interest in scoring the contribution of different sources of income to livelihood and access to credit. Economic capital is a proof of household capacity to respond to financial crisis and of the development of the local community.

Table 3: Economic capital set of indicators

EC= (FC+PC)/2		
		FC1.1: Livestock share in in total income

FC =(FC1+FC2+FC3)/3	FC1: income sources diversity	(%)
	FC1=(FC1.1+FC1.2+FC1.3)/3	FC1.2: Contribution of farm income to total household income (%)
		FC1.3: contribution of off-farm oncome to total household income
	FC2: Income level	FC2: Income level against poverty threshold (total household income/ country poverty threshold)
	FC3: access to credits FC3= (FC3.1*FC3.2)	FC3.1: existence of reliable allowance for borrowing (if yes then 1, if not 0)
		FC3.2: occurrence of critical shortage because of lack of funds for farming activities (if yes then 1, if not 0)
PC =(PC1+PC2+PC3)/3	PC1: Machinery	PC1: machinery value in local country currency
	PC2: Transportation	PC2: cars and trucks value in local country currency
	PC3: Livestock	PC3: Livestock: number of heads (total cattle and small ruminants)

Social capital indicators

Social capital is divided to two categories as well: human capital and cognitive capital. Human capital consists of scoring the educational level, dependency ratio and farming experience within a household. Social participation, interaction and openness in addition to structural organization are sub-indicators of cognitive capital. Social form of capital is the most complicated to measure and least understood (Jarzebski et al., 2016), for this study, we tried to simplify the choice of indicators to reflect the social and organizational state of identified social-ecological systems.

Table 4: Social capital set of indicators

	SC= (HC+CC)/2	
		HC1: share of household members who

HC: Human capital HC= (HC1+HC2+HC3)/3	HC1: Dependency ratio	are less than 14 and more than 65 compared to the share of those between 15 and 64
	HC2: Education level	HC2: share of household members who have attended education institutions above elementary (%)
	HC3: Farming experience	HC3: number of years spent on farming
CC: Cognitive capital CC= (CC1+CC2+CC3)/3	CC1: Participation CC1= (CC1*CC2)	CC1.1: a household member is a member in a local organization (if yes then 1, if not 0)
		CC1.2: Had the household participated in a workshop during the last 12 months (if yes then 1, if not 0)
	CC2: interaction and openness CC2= (CC2.1+CC2.2)/2	CC2.1: number of times household members interacted with private or public research institutions during the last 12 months
		CC2.2: number of times household members interacted with neighbor farmers, cooperatives, farmers organizations and media during the last 12 months
	CC3: organizational structure CC3= (CC3.1*CC3.2)	CC3.1: reliance on government support (if yes then 1, if not 0)
		CC3.2: Household members in community leadership role (if yes then 1, if not 0)
	CC4: Field training	CC4: number of times household had participated in field training days during the last 12 months.

Resilience assessment: Indicator scaling and capital scoring

Capital indicators are either qualitative or quantitative, formed by continuous, discrete or binary variables. Scores are based on either three grades scale (1: weak, 2: moderate, 3: strong) or four grades scale (1: weak, 2: moderate, 3: moderately strong, 4: strong) (Speranza et al., 2014). Therefore, continuous and discrete quantitative variables of three forms of capital, NC, EC and SC have been allocated scores from 0 to 3 or 0 to 4 according to the values obtained in the data set. Discretization, scaling and thus scoring are performed by SPSS (Statistical Package for Social Sciences) software. Because our data set contains a large number of binary variables and regarding the relevant information these data provide, we combined binary data into a set of two variables whenever they occurred and scored them upon the context and significance of the set. For example, in the case of natural capital, water availability(NC5) and soil physical state (NC4) are both binary variables, if soil state is judged good (by referring to soil fertility index) then it is 1 and water is also judged available (by referring to water quantity index) then it is another 1, the couple (NC4 1; NC5 1) receives 4 as an upper limit score, now if the water is available but the soil is not fertile, the couple (NC4 0; NC5 1) receives 3 because water is considered more important than soil fertility in these contexts; in the opposite case (NC4 1; NC5 0) it receives 2 and finally, in case both are not performant, the couple (NC4 0;NC5 0) receives a 1 score. Another example of binary variables within the economic capital set of variables, if the household has reliable allowance that guarantee his access to credits (FC3.1) and he has not experienced any shortage in funds (FC3.2) then the couple (FC3.1 1; FC3.2 1) receives 4 as an upper limit score which not only the positive access to credits but also the household capacity to manage his allowance and assets. However, the couple (FC3.1 1; FC3.2 0) reveals that in despite of the existence of reliable resources for borrowing, the household is not able to have access to credits or is not able to manage the credits in case they occur and thus FC3 should receive 1 as lower limit score. A household who does not have access to credits and haven't experienced funds shortage (FC3.1 0; FC3.2 0) receives 3 and a farmer who does not have access to credits and have experienced funds shortage (FC3.1 0; FC3.2 1) gets a 2 score. The scores of each forms of variables were computed as demonstrated in tables 2, 3 and 4. This operation would be applied to every SES group of farmers issued from the clustering analysis in each country. The score of each form of capital, for each group is presented by the median value; median value is considered more representative of the central tendency of a set of values and it resists to outliers (Bryman et al., 2001).

NC, EC and SC median values were then utilized to calculate the Pr value as a main resilience determinant in our study. The three forms of capital determine the location of different SESs in the tri-capital space of resilience and Pr determines the distance that separates the SES from collapse point (Jarzebski et al., 2016). The community Pr was computed using a distance equation that was derived from analytical spatial geometry (Leung and Suen, 1994), Eq (1):

$$\text{Eq (1):} \qquad Pr = \sqrt{NC^2 + EC^2 + SC^2}$$

Median values of capitals were used to calculate Pr values on household and SES level; regarding the generated median values, a common Pr scale was developed for the three countries of our study and which will be discussed in next section of results.

4. Results and Discussion

4.1. Case study 1: Jordan

The variables' set used in the typology of Jordan social-ecological systems resilience profiles, the list includes a total of 27 variables classified upon different categories (table 1). The variables as explained in Appendix 1 describe rural livelihoods and the agricultural system in addition to an explanation of resilience strategies already existing, through variables that characterize resilience determinants: buffer capacity, self-organization and capacity for learning. Farmers of Jordan sample showed low illiteracy rate and reliance on off-farm income; the sample is characterized by small size of land and small herd of livestock.

Typology of social-ecological systems resilience profiles

The first step of the analysis consists of generating a cluster analysis of farm types according to the social-ecological systems they belong to and to their resilience pattern. The factor analysis resulted in component matrix, each component, out of 9 total components, is composed by a group of aggregated variables and each variable has a coefficient that determines its importance. The components explain 75% of the variation within the data set and only variables with a coefficient superior to 40% were considered as determinants of components. Every component should be associated to at least one variable of social-ecological system categories and one variable of resilience determinants categories in order to generate social-ecological systems resilience profiles by means of *K*-means clustering method on a second step.

Cluster analysis resulted in the identification of four different group of farmers, characterized each by components of the previous factor analysis that determine specific criteria of social-ecological system and their resilience outlines (table 6).

The first identified group of farmers named J-SES1 *Mixed rainfed agricultural system* consists of 98 farmers. The average total land size is of 28 ha of which 88% are under rainfed crops. Livestock contributes up to 20% on average to the farm income, the herd size of small ruminants counts of 31 heads as a mean value. Whereas, farm income contributes to less than 50% of total household income. Therefore, family members, of whom 85% have attended educational institutions above elementary level, do have another off-farm income source such as public sector professions. Season cropped area share out of total land is around 87% while on average, 10.2% are left as follow land.

The second identified group is named J-SES2 *Rainfed agricultural system* incorporates 145 households whose main income source is based on off-farm activities. In fact, farm income contributes to only 15% of the total household income. Water resources are very rare and soils are not fertile according to soil fertility index. The average size of land on group level is less than 10 ha and the average ownership share of cultivated area is 43%, also on group level. The rainfed area share on total land is 64% while 8% of the land is used as follow land. Less than 20% of the households of J-SES2 declared that they have reliable resource that guarantee their access to credits in times of shortage.

The third social-ecological system issued of *K*-mean is J-SES3 *Mixed irrigated agricultural system*, it includes 29 households of Karaak study area, 40 ha is the average land size for this group and 42% is the share of irrigated area on average. The average number of small ruminants is 25 heads and they contribute averagely to 20% of the farm income. Water resources are abundant compared to the other three groups.

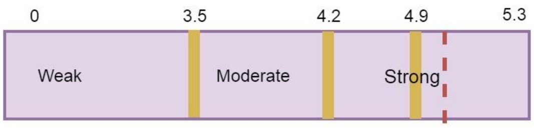
The lastly identified group is J-SES4 consists of 187 households, it is named J-SES4 *Tree-based agricultural system*, average land size is less than 20 ha with the largest share of the area allocated to tree-production, mainly olives. Minimum integration of livestock is highlighted with a contribution to farm income that is less than 8%. Soil fertility index is relatively better than other identified groups and household self-organization capacities are also judged better, households are more implicated and visit extension offices at least twice per year.

Resilience measurement and scaling: Tri-capital framework application for Pr calculation

This section objective is to deliver an accurate feedback on resilience level for a prospective sustainable intensification for each type of social-ecological system. Sustainable intensification instruments have to be adequate and relevant to the human-natural context in order to undertake the system's ability to transformation without falling to the breakdown point. We determine system's resilience level by calculation of Pr value which gives an assumption on how far it is from the collapse point.

The Pr calculation is a sum of the three forms of capitals NC, EC and SC, it recognizes the contribution of each capital form to maintain the stability of the SES within his basin of attraction. According to the obtained Pr values, we classified resilience levels: weak, moderate and strong (figure 5); This scale is actually applied to the three case studies of Jordan, Tunisia and Morocco. If Pr is ranged between 0 and 3.5, the SES is considered weakly-resilient, we talk about a moderate resilience if Pr value is more than 3.5 to 4.2 and it is a strong resilience if the Pr calculated is more than 4.2 to 5.28. However, a Pr value superior to 4.9 is not desirable and resilience is considered negative when it translates the resistance of a system to a necessary transformation or a positive change.

*Figure 6: Resilience level scale by Pr value**

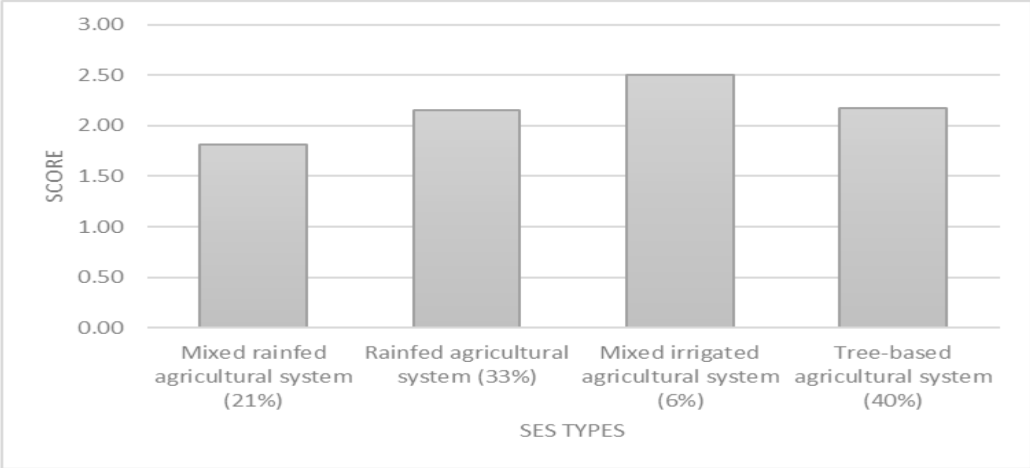


Source: own elaboration upon the obtained Pr value adapted from jarzebski et al. (2014)

*please note that this same scale has been used to assess resilience level in the three countries, according to the Pr value obtained in each and who also range from 0 to 5.3.

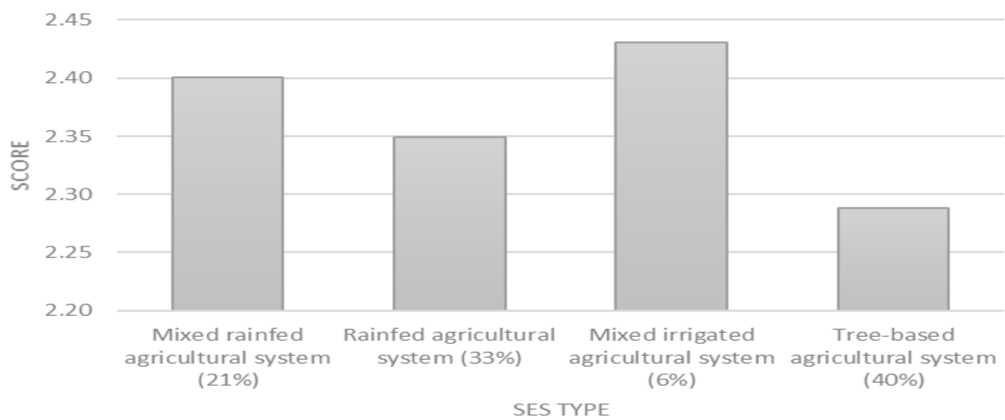
Natural capital is a significant indicator of farmers' capacities to manage natural resources and to evaluate their natural flows. A low score of natural capital indicators highlights the need of actions that target, not only the preservation of environmental services and stocks but also the improvement of household kills regarding land and resources management. Within the four identified SESs in Jordan, household natural capital scores ranged between 1, for a household of the J-SES1 "mixed rainfed agricultural system", and 3 for a household of J-SES4 "tree based agricultural system". J-SES1 "mixed rainfed agricultural system" has the lowest median value recorded among the other groups, which is 1.81 due to the lack of water resources and a low impact of physical size per member of household indicator. While, J-SES "mixed irrigated agricultural system" has the highest NC median value score which is 2.51 due to water availability.

Figure 7: NC median value per type of SES-Jordan



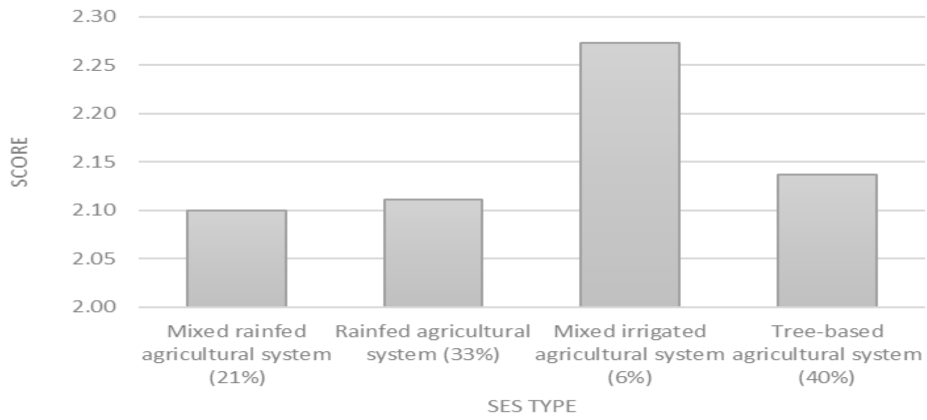
The highest EC median value (2.43) is obtained at J-SES3 "mixed irrigated agricultural system", households of this group represent a higher physical capital score compared to other groups thanks to the prominence of livestock emphasized in a higher number of small ruminant heads. On the other hand, livestock high contribution to income in addition to crops income, gives this group a good income diversification index and thus a higher financial capital score. Livestock pertinent contribution to economic capital is also highlighted among J-SES1 "mixed rainfed agricultural system" who scored an EC median value of 2.40. Economic capital, on average along the overall sample, is highly scored thanks to the importance of off-farm income contribution to total income.

Figure 8: EC median value per type of SES-Jordan



Social capital highest individual value is 3.06 recorded for a household of J-SES4 "Tree-based agricultural system" and the lowest one is 0.75 recorded for a household of J-SES1 "mixed rainfed agricultural system". Social capital indicators measure household participation and openness within their local community and involvement in local organizations in addition to their cognitive skills. Social capital score gives feedback on household capacity for learning and for enhancing their livelihood. The highest median value is 2.27 scored at J-SES3 "mixed irrigated agricultural system", households of this group have high social interaction score and educational level, they attend field training days and workshops which reveals their aptitude to upgrade their skills and this has a significant influence on the enhancement of their economic capital and thus the Pr value.

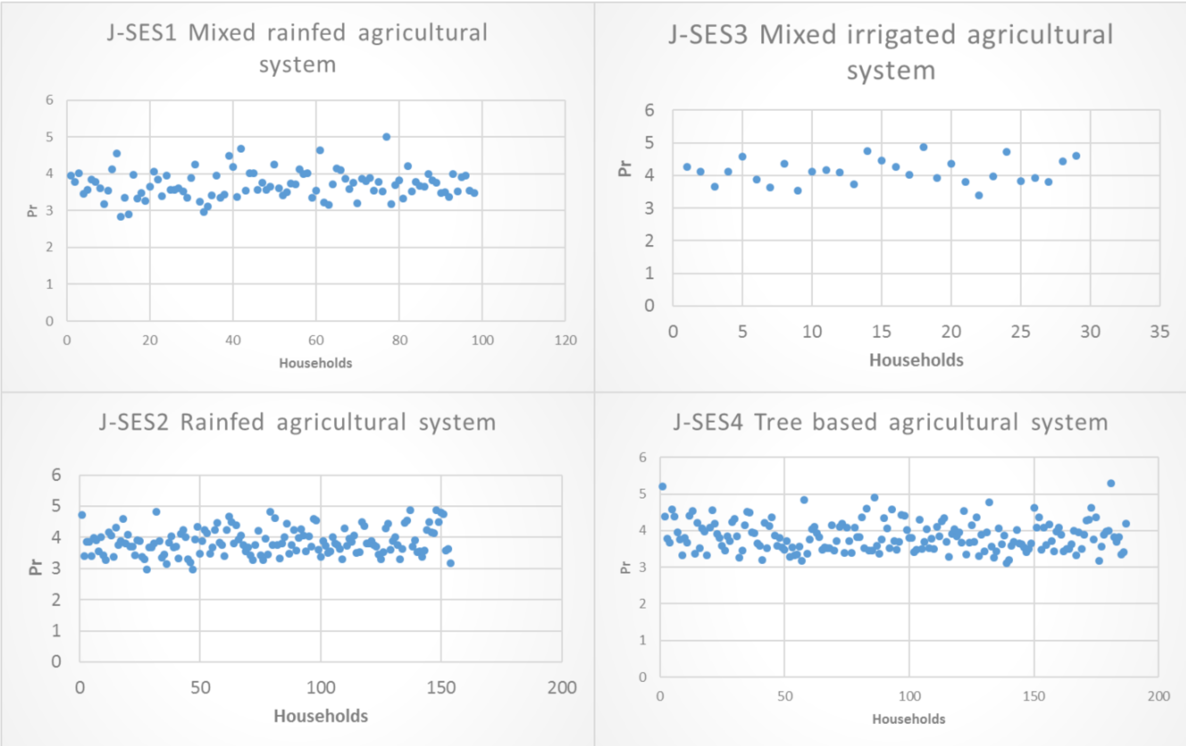
Figure 9: SC median value per type of SES-Jordan



Pr values for the different social-ecological systems identified in Karaak-Jordan vary between 2.83, as a lowest value obtained at household level of the J-SES1 "mixed rainfed agricultural system", and 5.28 as a highest value obtained at household level of the J-SES4 "tree-based agricultural system". households that are considered moderately-resilient, with a Pr value between 3.5 and 4.2, count 54% of the overall sample while only 20% are weakly-resilient with a Pr value less than 3.5. Karaak-Jordan householders have relatively good social indicators such as share of family members with educational level above elementary and hosting scientific demonstrations. Moreover, the important contribution of off-farm income to household total income increases EC indicators score as the total income rises and has different sources. Thereby, comparatively high scores of social capital and economic capital engender a household who is relatively distant from the breakdown situation and able to endure an adequate intensification intervention.

J-SES3 "mixed irrigated agricultural system" incorporates 41% strongly-resilient household (a Pr more than 4.2), 48% are moderately-resilient and only 7% are weakly-resilient. The median Pr value for this social-ecological system is 4.20 which is located on the edge between moderate and strong resilience along the resilience scale. Water availability enhanced natural capital indicators scores and livestock production enhanced physical and financial capital indicators scores, with relatively high social capital scores, the result is a balanced contribution of three forms of capital which engendered relatively resilient households. Whereas, in the case of J-SES1 "mixed rainfed agricultural system", because of the shortage in water resources, the NC indicator score is low (1.81) and thus the contribution of EC an SC to Pr value are more important. Hence, 62% of households of this group are moderately-resilient and only 7% are strongly-resilient. Unlikely, households who do not have a good economic or social capital are weakly-resilient and they represent 30% of individuals of this group. Both social ecological systems are adept to host an operational sustainable intensification that target the deficient for of capital of the household or the group. J-SES2 "rainfed agricultural system" and J-SES4 "tree-based agricultural system" have respectively 55% and 58% of their household classified as moderately-resilient however, also respectively 30% and 24% are weakly resilient. Both groups have similar median values of natural capital indicators score while EC and NC median values are different. J-SES2 scored higher economic capital due to the fact that household of this group mostly cultivate cereal and they have access to mechanization. On the other hand, individuals of J-SES4 “tree-based agricultural system” have shown better social participation and self-organization and thus the group have a slightly higher NC median value than J-SES2.

Figure 10: Distribution of households by Pr value by type of SES in Karak-Jordan



4.2. Case study 2: Tunisia

The variables used in the typology of social-ecological systems in Sidi Bouzid governorate in Tunisia are described in Appendix 2 the list includes a total of 22 variables that describe rural livelihood beside adaptive and self-organization capacities and their aptitude to learn. Descriptive analysis revealed that the average farm size of the sample is 8.5 ha. Only 10% have access to water and cultivate irrigated crops, Jelma sub-district only bares 2% of the governorate deep wells and no more than 10% of its shallow wells. For more than 70% of households, agriculture is the main source of income. Livestock production is however important; it has the second largest number of sheep in the governorate, equivalent to 13% of total number of heads.

Typology of social-ecological systems resilience profiles

At a first level, the factor analysis generated a component matrix that includes different groups of variables aggregated into components. The component matrix also presents the importance, or the width, of each variable in defining each component. The principal component analysis resulted in eight components, as shown in table 7, which explain 61.7% of the overall variability among the data set. For each component, only variables with a regression coefficient superior to 40% are considered and associated to that component, as revealed in table 7. Coherently with the objective of this first step of the analysis to develop a typology of social-ecological systems resilience profiles, each component should be associated to at least one variable of social-ecological systems categories and one variable of resilience determinants categories.

After finalizing the factor analysis and the determination of different components, we proceed to a clustering analysis in order to group different types of farmers upon their socio-ecological characteristics and resilience strategies. *K*-means clustering method resulted in an identification of four different groups of farmers, each of the groups is characterized by a set of variables, or components, as represented in table 8 The first group named T-SES1 *Medium rainfed cropping systems with livestock integration,* it consists of 166 observations, the equivalent to 66.5% of the overall sample, they are medium size farms with an average land size of 13 ha. The agricultural system is a rainfed cropping system with an integration of cattle and sheep production, the average number of heads is 15. Resilience determinants are irrelevant in this social-ecological system, as buffer capacity is low as well as self-organization and capacity for learning, extension services are not accessible within the community, beside farmers tend to conserve old farming practices and to be less interested in social networking or research involvement; they have low interaction with neighbors, as well as with research institutions indexes.

The second SES resilience profile identified is named T-SES2 *Small tree-specialized cropping system*, it presents 12% of the total sample, the average land size is less than 10 ha, they are all tree-specialized cropping systems with a low integration of livestock, comparably to other groups, only 40% of the income is generated by livestock production. The total average tree-cropped area is 55%. Farmers of this social-ecological systems are more open to social interactions with neighbors, NGO's and cooperatives, they also have more access to extension services and at least a household member is active at a local organization. Self-organization and capacity for learning indicators are relatively higher than the first and third clusters.

A third SES resilience profile, is named T-SES3 *Large rainfed cropping system with high livestock integration*, it presents 16% of the overall sample, the average land size is 20 ha; livestock production, which is based on small ruminants, contributes to almost 67% of total farm income. Total farm income is high which gives the farmers of this group relevant economic status compared to the rest of the groups. This is due to the importance of livestock contribution in addition to crops income. Social indicators related to self-organization and capacity for learning are, however, irrelevant.

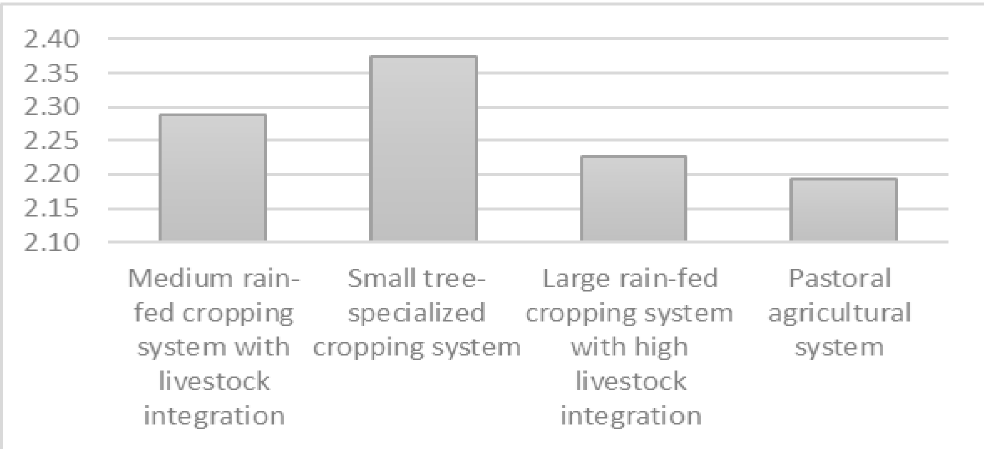
The lastly-identified SES resilience profile reassembles farmers who rely exclusively on livestock production as it contributes up to more than 77% to the total farm income. It is named T-SES4 *Pastoral agricultural system* and it evolves farmers who have more than 30 heads of sheep and most of their land is a fallow land. Social and economic indicators are very important among this group and emphasize their capacity to mitigate risk.

Resilience measurement and scaling: Tri-capital framework application for Pr calculation

The second step of the analysis consists of the quantification of resilience to deliver an accurate feedback for a potential sustainable intensification. In this part, we discuss results obtained after calculation and scoring of three capitals; natural, economic and social, beside the determination of Pr value per cluster, the level of resilience and the position of individuals of each cluster in relation to the collapse point.

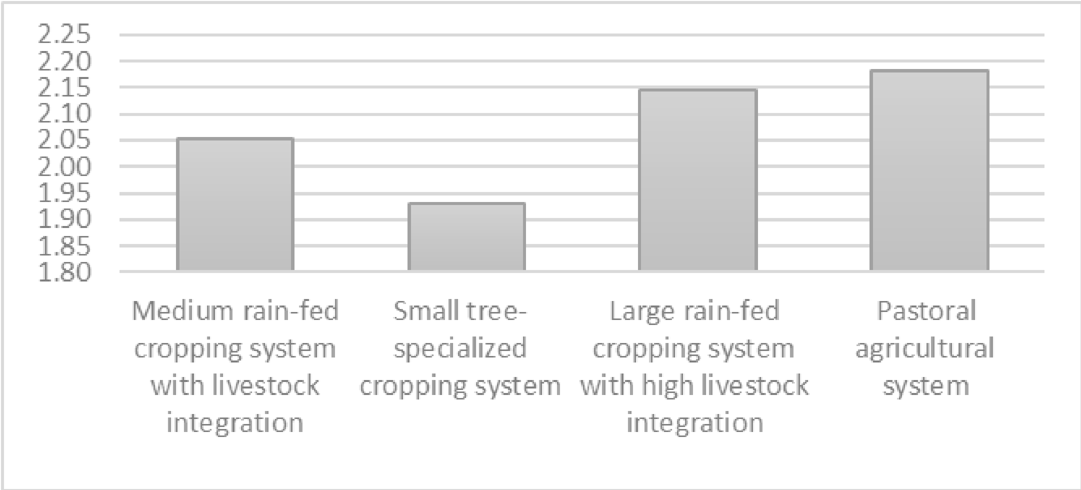
The indicators used in the calculation of natural capital are relevant in terms of determining localized livelihood of communities, the scores obtained among different groups of SESs vary from 1.25 as a minimum score and 3.5 as a maximum score. The "medium-sized rainfed cropping system" have a moderate median value of natural capital (2.28), which is explained by the importance of the income share generated by crops production, beside, the share of season cropped area compared to total area is high in addition to an overall good state of soil. The highest NC median value (2.37) is registered within the second identified SES of "small-sized tree specialized cropping system", land ownership and physical land size indicators in this group are very important indicators as well as that the total area is under permanent crops (trees) which engenders a high score for land use indicator, some farmers do also have access to water resources. Regarding the third and fourth groups whose agricultural activities are mostly oriented towards livestock production, the NC median values are consecutively 2.28 (large rainfed cropping system with high integration of livestock) and 2.19 (pastoral agricultural system) (figure 5).

Figure 11: Median NC value per type of SES-Tunisia



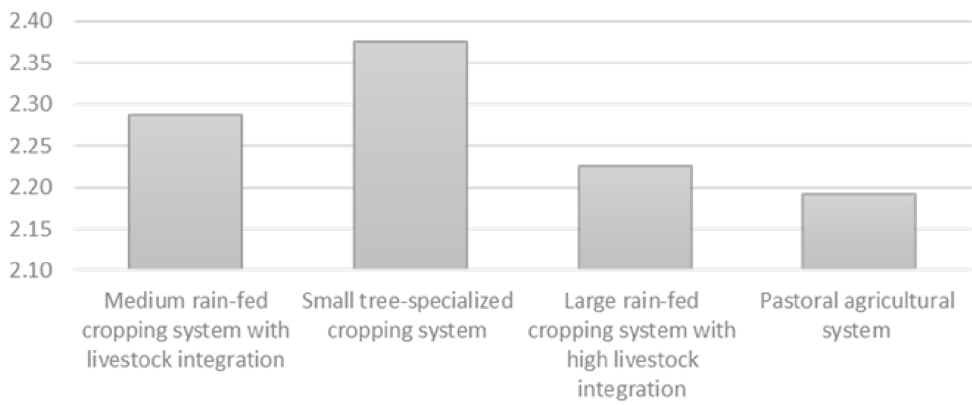
The most important EC median value is 2.2 obtained within farms of "pastoral agricultural system" group. It is the result an important physical and financial indicators scores, livestock production is a definite source of income and a livelihood determinant (figure 6). A relatively high EC median value of 2.14 is also obtained at the third identified SES (large rainfed cropping system with high livestock integration), in fact, it explains the significance of income sources diversification, if rural households have different income generation means then they are more secure in terms of economic capital and their resilience level is therefore enhanced.

Figure 12: Median EC value per type of SES-Tunisia



Social capital indicators highlight the level of education within rural households, their openness to social networking and willingness to learn and improve their skills; it sheds the light on the crucial role human agency plays within an SES and the necessity of structural intervention for NC enhancement within rural populations. The highest median SC value (2.62) was obtained within the T-SES4 "pastoral agricultural system" households; they demonstrate a relevant level of community cognition. The lowest SC median value (1.83) was however registered within individuals of T-SES1 "medium sized rainfed cropping system with livestock integration" (figure7). The T-SES2 "small tree-specialized cropping system" households are also robust in terms of social capital, a median SC value of 2.05 was registered; which is not the case of the "large rainfed cropping system with high livestock integration" households, they have less social interactions and not involved in local organizations or taking leadership roles among their communities.

Figure 13: Median SC value per SES type-Tunisia

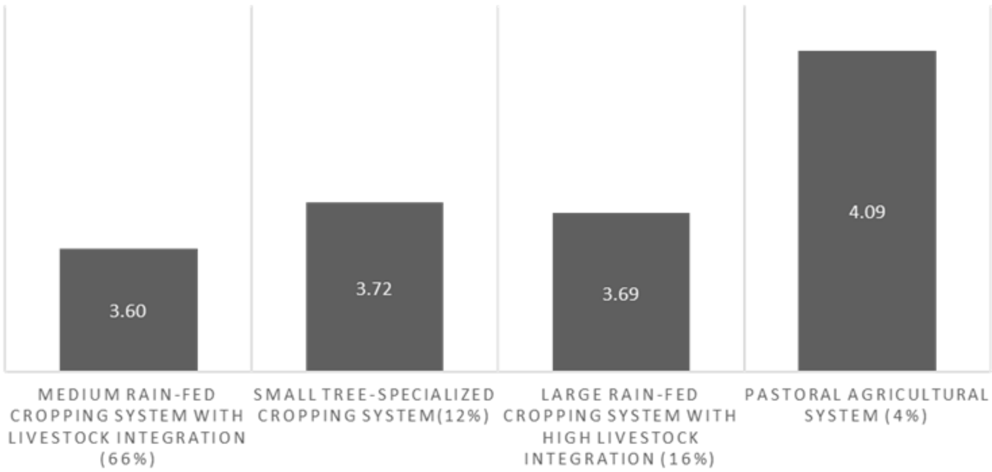


The Pr calculation is a sum of the three forms of capitals NC, EC and SC, it recognizes the contribution of each capital form to maintain the stability of the SES within his basin of attraction. According to the obtained Pr values, we classified resilience levels: weak, moderate and strong. If Pr is ranged between 0 and 3.5, the SES is considered weakly-resilient, we talk about a moderate resilience if Pr value is more than 3.5 to 4.2 and it is a strong resilience if the Pr calculated is more than 4.2 to 5.28. However, a Pr value superior to 4.9 is not desirable and resilience is considered negative when it translates the resistance of a system to a positive change.

The first group of SES "Medium rainfed cropping system with livestock integration" includes the largest number of households who are weakly-resilient, 39% with a Pr value less than 3.5; regardless of relatively good natural capital indicators. It also has the lowest median value of Pr. In fact, most of the weakly-resilient households of this group are disadvantaged in terms of economic capital; they don't have access to credits and have experienced financial shortage because of lack of funds for agricultural activities, the share of livestock contribution to farm income is low and their income level is less or equal to the poverty threshold in the country. On another side, their social capital demonstrates the fragility of the community regarding social networking and cognition, the openness scores, either to neighbors and local organizations or to research institutions, are very low. Besides, the participation in field days and workshop attendance rates are low. In the same SES, the households who are considered moderately-resilient, could compensate the shortage in EC and NC with a relatively higher NC; it is the result of good land ownership indicator score, which does also improve their access to credits, as well as to a good water availability index. In despite of the differences in capital accumulation between the T-SES2 of "small tree-specialized cropping system" and the T-SES3 of "large rainfed cropping system with high livestock integration", the distribution of their household along resilience scale, according to Pr values, is similar to a certain extent, they present a median Pr value of 3.72 and 3.69 respectively. The share of moderately-resilient households of T-SES2 and T-SES3 is 48% and 49% respectively; similarly, the share of strongly-resilient households is 16% for T-SES2 and 15% for T-SES3. Both of SESs have good natural capital level, due to high land ownership and season cropped area rates. Moderately-resilient farms of T-SES2, are more involved in community networking and learning capacity development, they participate in field training days and attend workshops, they also consult extension services. Therefore, their social capital is relatively high while the economic capital is lower (1.93).

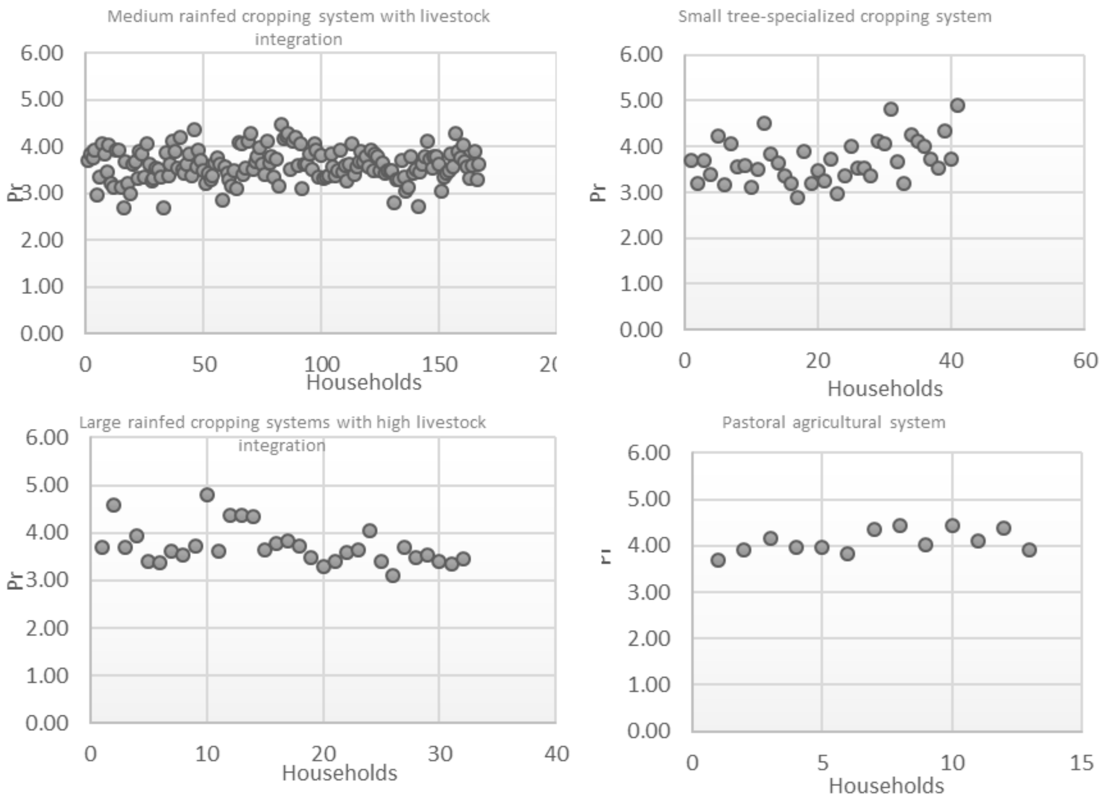
Moderately-resilient farms of T-SES3 present an important EC contribution (2.15) to Pr value, farm income is comparatively high, particularly with the existence of a high livestock share and off-farm income sources, which improves income level against poverty threshold in the country. Although the fact they have access to credits, they are have experienced a financial shortage which reveals a low management capacity. This low management capacity might be emphasized by a relatively low social capital (1.96), household members are less involved in local organizations and rarely perform a leadership role within the community, they also have low interaction rates with national and international research organizations.

Figure 14: Median value of Precariousness per type of SES-Tunisia



The T-SES4, "pastoral agricultural system" includes only farms with moderate and strong resilience, 67% of households are moderately-resilient while 33% are strongly- resilient, it also has the highest median Pr value (4.09) which reveals the distance to breakdown point. Although the NC contribution to Pr is less important than other SESs, the EC and SC have relevant contributions and play an important role in building the resilience of the correspondent SES.

Figure 15: Distribution of households of each identified SES by Pr value-Tunisia



4.2. Case study 3: Morocco

The average land size of the sample is 8.9 ha; however, 55% are small farmers with an area less than 4 ha. Irrigated land represents on average 22% of the total sampled area. Farm income contributes to a major part of total household income, 33% is the share of irrigated crops contribution while rainfed crops provides 34% of the income, livestock presents only 18%, on average, of the total household income. The illiteracy rate is high among the sample, about 50% do not have any educational background while only 2% have a university degree. Membership in organization rate is 12%, mostly cooperatives and solely 4% of household members across the three areas have had a leadership community role.

Typology of social-ecological systems resilience profiles

The first step of analysis consists of the establishment of social-ecological systems resilience profiles typology, the list of variables includes 27 variables (Appendix 3), similarly to the two previous case studies, differentiated into different categories: demographic characteristics natural assets, physical assets, financial assets, buffer capacity, self-organization and capacity for learning. A principal component analysis resulted in the aggregation of variables of different categories into 9 components (see Appendix) each variable has a coefficient that determines its standing, we only keep variables with a coefficient superior to 0.40; the total variance explained is 65.81%.

Once principal component analysis was achieved, we proceeded to a *k*-means clustering analysis which engendered different types of farms recognized by their social-ecological dynamics and resilience patterns. The first group named M-SES1: *Mixed rainfed agricultural* *system* is the largest identified group with 281 households. It is characterized by rainfed cropping practices with a low integration of livestock, exclusively cattle, and a number of heads that does not exceed, on average, 4 by household. The farmers of this group are mostly small farmers, 196 out of 281 households, equivalent to 70%, with a land size less than 10 ha while only 30 households (10%) have more than 20 ha of land. The average share of owned land over the total cropped area among the group is less than 50% with an average household age of 55 years old and an average dependency ratio superior to 1.2, these factors reveal a low buffer capacity. Moreover, household access to extension services is limited and so are interactions within rural or research networks and social participation.

The second identified group M-SES2: *Pastoral agricultural system* reassembled farms whose vocation is founded on livestock production. It consists of 15 households; on average, at least 4 members of the household have an educational level above elementary. Livestock is a major source of income; principally small ruminants whose average number of heads is 19 per farm while cattle average number of heads per farm is only 4. The M-SES2 members have a relatively better aptitude to self-organization, they frequent more extension offices than the other two groups, a minimum of twice per year, their capacity for learning is also emphasized in the number of times they participated in field training days or organized workshops per year as well as their openness to other farmer in the neighborhood or within agricultural organizations such as cooperatives.

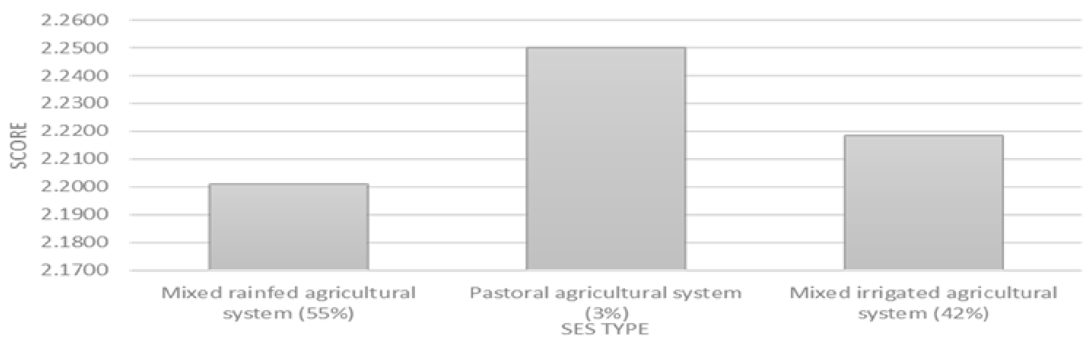
Thirdly-identified group M-SES3: *Mixed irrigated agricultural system* assembled 213 farmers, whose main agricultural activities are based on irrigated crops with an integration of livestock production. It is also characterized by small farmers with less than 5 ha of land on average, 64% of this group households have less than 2 ha of land. Livestock integration to crop production only produces around 18% of the farm income. Households depend on auto-consumption of their own garden products to meet their nutrition needs; on average, at least 1 member of the family have an above-elementary educational level, extension service visits to the household are not prominent however members of the family might visit the extension services office at least once per year.

Resilience measurement and scaling: Tri-capital framework application for Pr calculation

At this section we proceed to the interpretation of the results issued out of the second step of the analysis applied to Morocco case study. For each identified social-ecological system resilience profile, we discuss the outcomes of capital quantification through the scoring of previously-selected indicators, as well as the results of Pr value calculation. This relates to the median values, three forms of capitals beside resilience levels for each M-SES group of farmers and for households within each M-SES group.

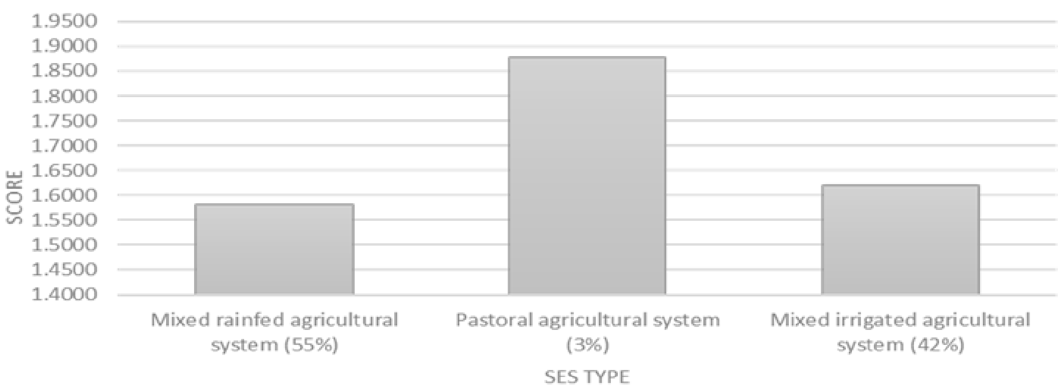
Natural capital indicators scoring revealed that Meknes region in Morocco bares a relatively good natural flows thanks to the existing of commonly-owned and privately-owned water sources along the studied area. However, the fragmentation of land, the largest range of household are small farmers with low land ownership share and limited income, reduced their buffer capacities. The lowest registered natural capital median score is 2.20 at M-SES 1 “Mixed rainfed agricultural system” while the highest natural flows score was registered at M-SES2 “Pastoral agricultural system” just because farmers of M-SES2, in despite of the small size of their lands, they are the owner of these lands and the season cropped area percentage is averagely 90%.

Figure 16: Median value of NC per type of SES-Morocco



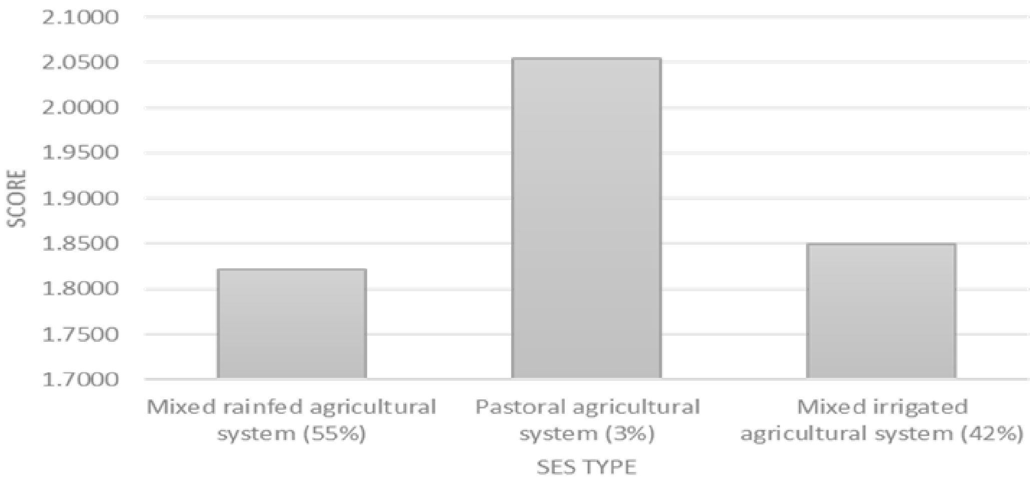
Economic capital individual scores, for the overall Morocco sample, ranged between 0.83 as a minimum value, obtained for a household of M-SES1, and 3.17 obtained for a household of M-SES2, a group that is characterized with the abundance of livestock-generated income. On the other hand, the lowest median value of economic capital scores is 1.58 recorded at M-SES1 "mixed rainfed agricultural system", whereas M-SES 2 "pastoral agricultural system" had the highest EC median score (1.98). Physical capital along M-SES 2 households is highly scored thanks to small ruminants and cattle number of heads, which does also constitute a reliable source of funds in times of crisis.

Figure 17: Median value of EC per type of SES-Morocco



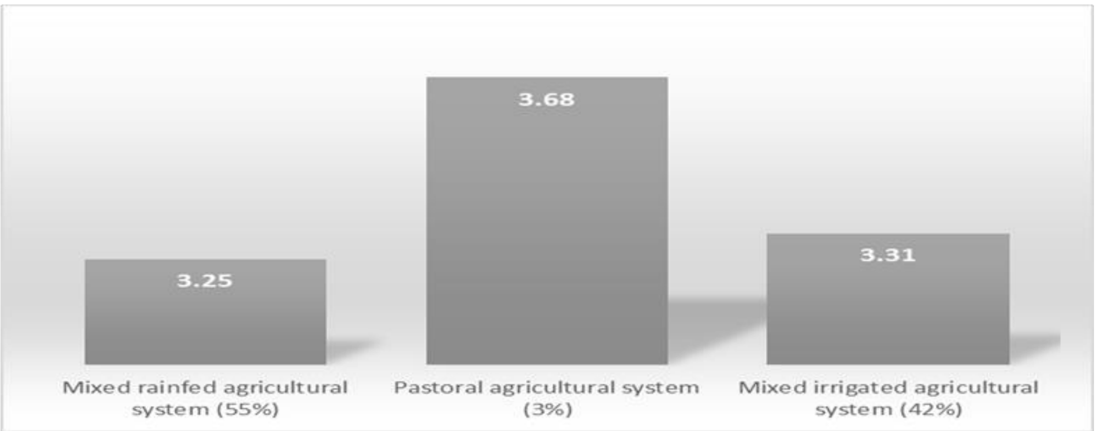
Social capital indicators scores, on household level, were ranged between 0.83 as a minimum score and 3.21 as a maximum score. The SC indicators have emphasis on diagnosing, on a household level and on community level, human capital on one hand and cognitive capital on the other hand. The second group of farmers M-SES2 "pastoral agricultural system" does also have the highest median social capital indicators scores (2.05), household members of M-SES2 have a better educational level and are showed better capacities of self-organizations and willingness to learn. Contrarily to M-SES2, the M-SES1 and M-SES3 had a lower median social capital score, 1.80 and 1.84 respectively due to less social interaction and involvement within local community, in addition to weak learning abilities.

Figure 18: Median value of SC per type of SES-Morocco



The recorded individual Pr values vary from 1.99 a minimum value registered at the M-SES3 to 5.21 obtained at a household level also belonging to M-SES3 “mixed irrigated agricultural system”. According to the obtained Pr values, we classified resilience levels on three categories: weak, moderate and strong. If Pr is ranged between 0 and 3.5, the SES is considered weakly-resilient, we talk about a moderate resilience if Pr value is more than 3.5 to 4.2 and it is a strong resilience if the Pr calculated is more than 4.2 to 5.28. However, a Pr value superior to 4.9 is not desirable and resilience is considered negative when it translates the resistance of a system to a positive change.

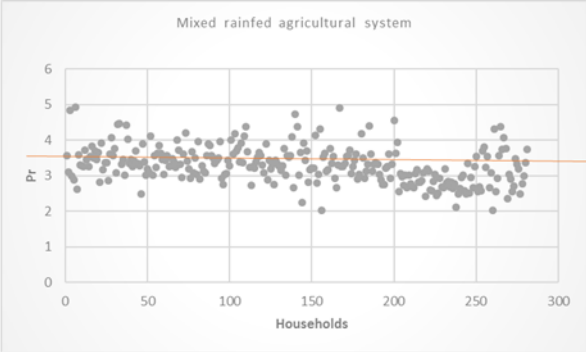
Figure 19: Median Pr values per type of SES-Morocco

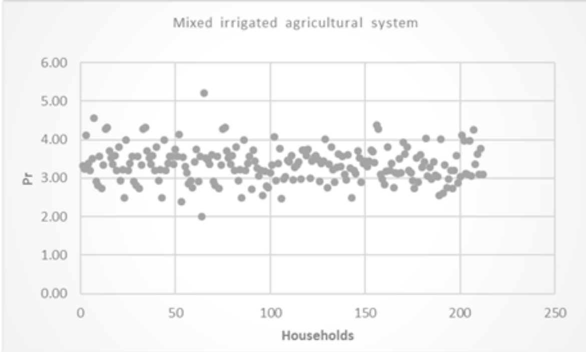


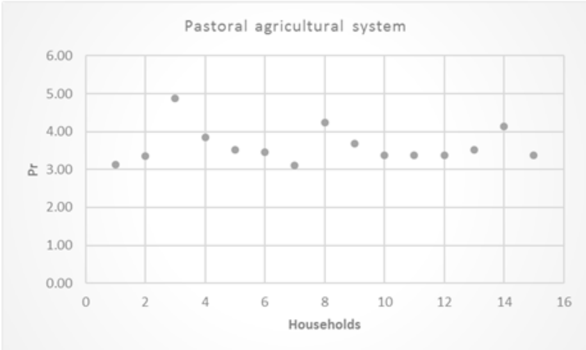
In the case of Meknes region in Morocco, it is interesting to study the differences in economic, natural and social stocks, beside Pr value and resilience level, between farmers of the same group. M-SES1 “mixed rainfed agricultural system” has 67% of its household with a less than 3.5 Pr value, they are considered as weakly-resilient, only 5%, the equivalent to 14 households, were identified strongly-resilient. Social capital indicators illustrate that households of M-SES1 present a high illiteracy rate and a low cognitive capacity, they don’t participate in workshops or field training days, the interactions with local community organizations or research institutions also rare and so are interactions with neighborhood farmers. This social isolation inhibits farmer capacities to learn and improve their farming skills. One more general criteria of Morocco sample, and specifically M-SES1 is the land size, most of farmers are small farmers, with little land and minimum integration of livestock production for extra source of income. The income, however, remains low and

this is emphasized in the average total income that is not pertinent compared to countries poverty threshold. The 28% moderately-resilient households, to only 2 among the M-SES1 farmers, achieved a Pr value between 3.5 and 4.2 thanks to higher natural capital scores, they have large exploitations and the season cropped area comparted to total area share is important, which also gives them better buffering capacities against economic crisis and thus a relatively higher Pr value that allows them to be declared moderately-resilient.
The M-SES3 “mixed irrigated agricultural system” has a very similar distribution of its households along the resilience scale according to Pr values. Within M-SES3 group, there are also above 60% of weakly-resilient households, 29% are moderately-resilient and only 5% are strongly-resilient. In despite of the existence of water resources and that more than 80% of the total agricultural area in this group is under irrigated cropping systems, however land fragmentation and very limited economic resources limit farmers’ capability increase their income, more than the small size of land, the share of cropped area is also low and production is oriented towards auto-consumption. The income sources, although diversified: crops, livestock and off farm, they contribute to low total income on household level. M-SES3 economic and social forms of capital scores are slightly higher than M-SES1 (5% difference), and they have almost the same natural capital score which explains the similarity in Pr values and heterogeneity in household distribution along the resilience scale.
Pr values, determining resilience levels of households and SESs, are nothing but a sum of three forms of capital contributions, which reveals that in case of M-SES1 and M-SES2, government intervention should target improving the social capital within each SES, at a first place, and then the economic capital, to improve farm management capacities of households, social participation and cognition, in order to improve their economic and social status and thus their resilience level.
M-SES2 “pastoral agricultural system” median Pr value is 3.68, which is higher than the median Pr values obtained at the level of the other two identified SESs. The moderately-resilient households share at this group is 47%, while the strongly-resilient households represent 11% of the total observations. If we compare the median scores of M-SES2 EC, SC and NC, to the other two groups, we can see that M-SES2 “pastoral agricultural group” has higher median scores of EC and SC, which is due on one hand to the physical capital consisting on livestock herd size, to the financial capital emphasized in livestock important contribution to income and to better social indicators.

Figure 20: Distribution of households of each identified SES by Pr value-Morocco







4.3. Final remarks for a cross-country observation

One of the highlights of this study, is the feedback that relates resilience assessment and scaling to the three dimensions of sustainable intensification, sustainability is not the adverse of intensification anymore as long as the premise of evaluating interventions and investments, that tend to promote intensification, is fulfilled. It is also revealed important, the characterization of different social-ecological systems in dry land regions. Regarding the diversity of system components and the complexity of interactions and dynamic links of subsystems in dryland regions, it became crucial to understand the nature of relationship between agricultural and ecological systems on one hand and human agency including socio-economic and cultural context on the other hand. The typology applied to the different agricultural production systems of the three different countries approved the assumption over social-ecological systems diversity in space and scale, we could recognize up to four different social-ecological system types in the lamp of limited landscape, representativeness of identified farm types is significant. Vulnerability is not only generated by natural resources shortage and low natural capital or even financial flows, low management capacity of these resources and absent self-organization skills beside little capacity for learning are also factors that inhibit household potential for intensification. Thus, quantification of resilience through accumulation of the three forms of capitals: economic, natural and social; and Pr calculation, allowed to determine the weaknesses at household level, at a first step, and on social-ecological system at a second step. If the weakness or vulnerable sub-component of a system is determined than interventions for sustainable intensification, policy and programs, should be planned dependently on these findings.

Results in the three countries have showed that in some cases, large scale farmers with good buffer capacity level, emphasized in high economic capital (access to credit, large herds, land property), are considered moderately-resilient just because their social capital is not high strong enough. Farmers with high social capital but irrelevant contribution of one or the two other forms of capitals are merely considered weakly-resilient. Therefore, one of the important implication of this study, is that guaranteeing a balanced contribution of the three forms of capitals results in an invulnerable household and an overall resilient social-ecological system. Resilience quantification also shed the light on the important role of livestock production in rural livelihood. Mixed production systems are well placed along the resilience scale and livestock constitutes a robust source of income, animal heads are one of the assets that could be mobilized at any time to respond to a financial shortage or other crisis. Livestock also strengthens rural livelihood by diversifying income sources and compensation of losses engendered by crop production due to climate hazards. Livestock producers also appear to be more engaged socially and more open to their neighborhood, this is mainly due to practicing transhumance and sharing rangeland with other farmers, which enhances their positioning over the resilience scale. Conventionally, the appropriate form of intensifying food production in drylands, is increasing inputs per unit of area, however, intensifying food production without engendering social and environmental costs, consists of investing not only in agricultural production inputs but also in human and cognitive forms of capital. The results also give an accurate feedback on current challenges or "need for actions" in rural space of MENA region in the light of the on-going rural transformation, it highlights the need of these countries to develop adequate policy solutions that are intrinsically linked to the available natural and economic capitals and with enhancement of social capital, in order to develop rural areas, in the light of an urgent intensification, without compromising their sustainability or inclusivity.

4.2. **Limits of the research:**

This study is one of the very first of its kind in MENA region, resilience measurement focused studies are still very limited; if not existing at all at most countries level. The already existing research have developed econometric models (linear regressions) such as Resilience Index Measurement and Analysis (RIMA model) used by Food and Agricultural Organization (FAO) to measure household resilience to food insecurity in Palestine by Mane et al. (2010). The relevance of our study is in taking into consideration the diversity of production systems and the diversity of the socio-economic context they are part of, we found out that even on a limited spatial scale, the assets and/or the vulnerability aspects of each system are different. We also developed composite indicators that reflect not only natural and economic assets of a household, but also that take into consideration its interactions within the different forms of organization and institutions in the local community or on a border spatial scale. However, as the indicators in this study are dependent on already existing data then, and considering the large sample sizes as well as spatial scale of the study and time limit, we could not have access to more accurate data to develop more representative indicators, that's why in future research, it is possible to develop more relevant indicators that could respond better to the capitalization theory. Another limit of this study, is that we were not able to define the maximum point of positive resilience, because a high Pr value translates a very strong resilience that might inhibit the system, in another case, to endure a transformation and adapt to positive change. Resilience analysis is still a very challenging research trend, the lack of instruments allowing quantification and scaling of resilience that is applicable in all contexts is also one of the incentives of this study, regarding the importance of resilience in drawing sustainable intensification paths. Nevertheless, tri-capital framework or RIMA model are only a base for larger perspectives of empiric research in this field especially that many theoretical frameworks have been developed but quantitative ones are still in shortage.

Conclusion

Social-ecological systems resilience analysis allows the application of resilience concept over a broad extent. Social-ecological systems are actually multipart systems that include complex relationships between two large sub-components; translated in demand/supply and actions/services interactions between natural and human subsystems. In matter of fact, every social-ecological system discloses its own specificities and major particularities that contribute to alternate a system state in the process of responding to external changes in the environment. If the system is able to present feedback loops on its state in an environment of heterogeneous patterns and processes, then institutional, technical and organizational interventions, instruments and tools, could be built to fit with system requirements and allow its sustainable intensification.

Capitalization framework does not only allow resilience scaling and gives a snap on system current state, it also allows the determination of anomalies within a system by the diagnosis of which capital has the lowest score and why is the household, at a first level, and the overall system at a second level, vulnerable; which will facilitate the intervention in order to reduce the vulnerability or to promote the intensification. It is important to highlight that a moderate resilience is due to balanced contributions of the three forms of capitals: natural, economic and social, and that livestock plays a relevant role in maintaining livelihoods in rural areas of MENA region and thus in strengthening household resilience. Our findings also suggest specific interventions for resilience management such as: Building social capacity by creating social networks that connect all stakeholders, providing incentives, and facilitating knowledge and information sharing as well as strategic investments to secure the sustainability of ecosystem services.

Resilience quantification and analysis, thus, is another tool to facilitate tasks of policy makers who face sustainability challenge on an ongoing basis particularly with the rural-transformation paradigm the world is undergoing and that is mostly affecting low and middle-income countries, such as MENA countries.

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APPENDIX1

List of variables used in the typology: for each country a number of selected variables of the list below have been used.

Category	Variable description	variable's name
Demographic characteristics	Age of HH* head	DC1
	farming experience	DC2
	Family total size	DC3
	% of family members with educational level above elementary	DC4
	Membership in a community organization (Yes, 1; if not then 0)	DC5
Natural Assets	total land (ha)	NA1
	share of rainfed area (%)	NA2
	Share of irrigated area (%)	NA3
	share of trees planted area (ha)	NA4
	share of fallow are (%)	NA5
	commonly owned source of irrigation (if yes then 1, if not 0)	NA6
	Privately owned water source (if yes 1, if not then 0)	NA7
	Water quantity index (if bad then 0, if medium or good then 1)	NA8
	Soil fertility index (if bad then 0, if medium or good then 1)	NA9
Physical Assets	Cattle –number of heads	PA 1
	Small ruminants -number of heads	PA 2
	Machinery value	PA 3
	transportation means value	PA 4
Financial Assets	Contribution of farm income to total income	FA1
	Contribution of livestock to farm income	FA2
	Income from rainfed crops	FA3
	Income from irrigated crops	FA4
	Total income DT	FA5
Buffer Capacity	Dependency ratio	BF1
	share of owned land in total exploited land (%)	BF2
	Existence of reliable source for borrowing (if yes 1, if not then 0)	BF3
	Use of garden products (1 if auto-consumed, 0 if other)	BF4
Self-Organization	Total visits of HH to extension offices	SO1
	Total visits of extension offices to HH	SO2
	Total information sessions attended by HH	SO3
Capacity for learning	number of hosted demonstrations on the farm for the HH within the last 12 months	CL1
	Interaction of HH with research institutions within the last 12 months	CL2
	Interaction of HH within his social context within the last 12 months	CL3
	Number of workshops attended by HH within the last 12 months	CL4

Source: Own elaboration

*HH: household

APPENDIX2

Components selected in principal components analysis in Karaak-Jordan

Component	Variables	Width
1	DC5: HH in community organization	0.40
	PA1: small ruminants number	0.43
	SO2: visits from extension offices	0.55
	CL2: Interaction with research institutions	0.74
	CL3: Interaction with other farmers and media	0.68
	CL4: field training days	0.80
2	PA1: small ruminants number	0.75
	PA2: Machinery value	0.51
	FA2: farm income	0.45
	FA6: livestock contribution to farm income	0.48
3	NA2: percentage of fallow land	-0.43
	NA5: Total area allocated to trees	-0.45
	BF2: Share of owned land of total cultivated area	0.60
4	DC4: members of HH with an educational level beyond elementary school	0.63
	NA3: percentage of irrigated area	0.41
	BF1: Dependency ratio	-0.55
5	FA1: off farm income (Jordanian dinars)	-0.40
	NA5: Total area allocated to trees	-0.51
	NA8: Water quantity index (good=1, bad and average=0)	0.46
	NA9: soil fertility index	-0.46
6	NA2: percentage of fallow land	0.62
	BF2: Share of owned land of total cultivated area	0.49
7	DC2: farming experience (years)	-0.54
	NA1: total land (ha)	-0.43
	BF3: Existence of reliable sources of credits	0.61
8	BF4: Main use of GARDEN produced crops -code: 0 does not have a garden, 1 auto-consumption, 2 commercialization, 3other.	0.79
9	NA8: Water quantity index (good=1, bad and average=0)	0.42

Source: SPSS output

APPENDIX 3

Components selected in principal components analysis in Sidi Bouzid Tunisia

Component	Variables	Width
1	FA5: total income in Tunisian dinars (TD)	.511
	SO2: number of visits of extension offices to household	.466
	SO3: total information sessions attended by household	.569
	CL1:number of hosted demonstrations on the farm for the HH within the last 12 months	.673
	CL2: Interaction of HH with research institutions within the last 12 months	.550
2	NA1: total land (ha)	.608
	FA3: Income from rainfed crops (TD)	.736
	FA5: total income in Tunisian dinars (TD)	.683
	SO3: total information sessions attended by household	-.401
3	NA2: share of rainfed area (%)	-.723
	FA2: Contribution of livestock to farm income (%)	-.424
	NA4: share of trees planted area (ha)	.624
	CL3: Interaction of HH within his social context within the last 12 months	.501
4	DC4: % of family members with educational level above elementary	-.551
	DC5: Membership in a community organization (Yes, 1; if not then 0)	-.419
	BF1: Dependency ratio	.459
5	NA5: share of fallow are (%)	.542
	CL3: Interaction of HH within his social context within the last 12 months	.485
6	FA2: Contribution of livestock to farm income (%)	.440
	FA4:Income from irrigated crops (TD)	.426
	BF3: Existence of reliable source for borrowing (if yes 1, if not then 0)	.500
7	PA 1: Cattle –number of heads	.555
	BF3: Existence of reliable source for borrowing (if yes 1, if not then 0)	-.407
	SO1: Total visits of HH to extension offices	.508
8	DC5: Membership in a community organization (Yes, 1; if not then 0)	.433

Source: SPSS output

APPENDIX 4

Components selected in principal components analysis in Meknes -Morocco

Component	Variables	Width
1	NA1: Total land in ha	.459
	NA3: share of rainfed area	-.422
	NA4: share of irrigated area	.407
	FA5: Total income	.563
	BC4: Main use of garden products	.482
	SO1: Total visits of HH to extension offices	.490
	SO2: total visits of extension offices to HH	.407
	CL2: number of times of interaction with research institutions	.570
	CL3: number of times of interactions within social context	.604
2	NA3: share of rainfed area	.756
	NA4: share of irrigated area	-.752
	PA1: cattle number of heads	.494
	BC4: Main use of garden products	-.461
3	DC5: Membership in community organization	.857
	FA2: contribution of in farm income to total income	.869
	SO2: total visits of extension offices to HH	.502
4	NA1: Total land in ha	.437
	PA1: cattle number of heads	.449
	SO1: Total visits of HH to extension offices	-.581
	CL2: number of times of interaction with research institutions	-.563
5	DC4: Family members with educational level above elementary	.527
	FA1: contribution of livestock to farm income	.447
	BC1: dependency ratio	-.555
6	NA7: privately-owned water sources	.694
	FA1: contribution of livestock to farm income	.436
7	NA5: share of fallow land	.559
	BC2: Total owned land of cropped land	.611
8	BC2: Total owned land of cropped land	-.408
9	PA2: small ruminants number	.698
	BC3: existence of sources facilitating access to credit in time of shortage	-.404

Source: SPSS output

Appendix 5

Program: Agris Mundus Master of science: University College Cork (Ireland) & Polytechnic University of Madrid (Spain)
Name of student: Maroua Afi
Subject of thesis: Analysis and measure of resilience in dry lands agricultural systems: a typology and assessment of resilience of social-ecological systems in Jordan, Morocco and Tunisia.
Period of Internship: April 4th, 2017 to September 30th, 2017
For October, November and December 2017, I am working as a research assistant at ICARDA regional office in Tunis-Tunisia.
Objectives achieved during the placement:
Data selected, cleaned and ready for use for three countries: Jordan, Morocco and Tunisia
Complementary data collection
Typology of social-ecological systems (SES) resilience profiles, in the three countries, using a set of variables that describes rural livelihoods and resilience determinants (identification of variables and indicators in recent literature)
Quantification of resilience in the three countries: consideration of different types of SESs identified from the typology in their "basin of attraction" in order to calculate their Precariousness, Pr (distance that separates them from the collapse point), through capital accumulation (Natural capital, Economic capital, Social capital)

Participation in conferences and potential papers:

ESA Mograne 2017-Tunisia:

- Participation in « La journée scientifique de l'Ecole Supérieure d'Agriculture de Mograne Décembre 2017 » with a presentation entitled : « *Intensification durable des systèmes de production agricole : Utilité et mesure du concept de résilience avec une application dans la région de Sidi Bouzid en Tunisie* » (The conference was held in French language)

Link : http://www.esamograne.agrinet.tn/index.php/fr/sample-data/item/109-programme-de-la-journee-scientifique-internationale-de-esa-mograne-2017

IFSA-2018-Greece

- Paper entitled "*Resilience Attributes and Measurement of Social-Ecological Systems Resilience in MENA Region: A Case Study of Jordan*" accepted to be presented on IFSA European Symposium 2018 in Greece, "Farming Systems: Facing Uncertainties and Enhancing Opportunities"

Link: http://www.ifsa2018.gr/

ICWEES 2018-Tunisia

- An abstract of a paper entitled "*Measurement of Socio-Ecological Systems Resilience in Tunisia: Innovative approach using Tri-capital framework*" submitted for participation at The International Conference on Water, Environment, Energy and Society ICWEES'2018.

Link: http://icwees2018.tn/

IAAE 2018-Canada

- A paper entitled **"Livestock for resilience": Revisiting the role of livestock in the major agricultural production systems of the MENA region"** has been submitted for participation at the International Conference of Agricultural Economics 2018 (IAAE 2018)
- An abstract entitled **"Comparative Assessment of Agricultural Production Systems Resilience and Scope for Sustainable Intensification across the MENA Region"** has been submitted to the same conference (IAAE 2018) in the framework of one of pre-conference workshops, organized by CGIAR PIM team, targeting rural transformation and sustainable intensification.

Link: http://www.icae2018.com/

AIEPRO 2018-Spain

- An abstract and potential paper is to be submitted to the 22nd AEIPRO International Conference on Project Management and Engineering –Madrid 2018. (on progress)

Link: http://congresso.aeipro.com