AMERICAN UNIVERSITY OF BEIRUT

APPLYING AN ECOSYSTEM APPROACH TO ASSESS BIOSPHERE RESERVE MANAGEMENT: THE CASE OF JABAL MOUSSA BIOSPHERE RESERVE

by
CHRISTINA PIERRE HACHEM MAJDALANI

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submitted in partial fulfillment of the requirements
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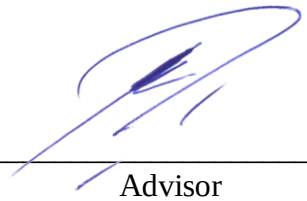

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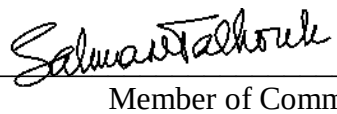

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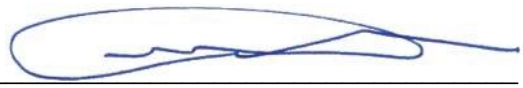

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ABSTRACT
OF THE THESIS OF

Christina Pierre Hachem Majdalani for Master of Science

Major: Ecosystem Management

Title: Applying an Ecosystem Approach to Assess Biosphere Reserve Management: The Case of Jabal Moussa Biosphere

The quest for a balance between sustainable development and nature conservation remains a challenge for scientific and spatial planning. This balance is especially complex in social-ecological structures focused on conventional rural practices and correlated with protected areas. The purpose of this study is to suggest concrete ways to enhance the management of the Jabal Moussa Biosphere Reserve. To achieve this goal, the research will explore the supply side of ecosystem services in the biophysical dimension, across different landscape units in Jabal Moussa. Tackling the supply side shows how the features of the environment determine the status of an ecosystem service. The supply side will be quantified by mapping the biophysical values of provisioning services focusing on agriculture production in the biosphere reserve's various zones, and the assessment will help to evaluate any bad management practices occurring in any of these zones. The indicators used for the biophysical assessment will rely on the LULC categories defined by the ArcGIS software and models from the INVEST tool. These value dimensions will be useful in evaluating the trade-offs of environmental resources affected by land management in Jabal Moussa Biosphere Reserve. Moreover, these findings can help identify areas where services are deteriorating, or conservation priority areas based on improving ecosystem services and will be useful in pinpointing problems associated with new planning and management practices.

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ABBREVIATIONS

Association for the Protection of Jabal Moussa – APJM

ARtificial Intelligence for Ecosystem Services –ARIES

Lebanon's National Center for Remote Sensing – CNRS

Ecosystem Services – ES

Food and Agriculture Organization of the United Nations –FAO

Geographic Information System – GIS

Global Biodiversity Modeling Framework – GLOBIO3

Global Unified Model of the BiOsphere –GUMBO

International Chamber of Commerce – ICC

Integrated Model to Assess the Global Environment –IMAGE

Integrated Tool to Value Ecosystem Services –InVEST

Internal Oversight Service – IOS

Jabal Moussa Biosphere Reserve – JMBR

Land Use and Land Cover – LULC

Man and Biosphere – MAB

Multi-scale Integrated Models of Ecosystem Services –MIMES

Ministry of Agriculture – MoA

Ministry of Environment – MoE

Sustainable Development Goals – SDGs

United Nations Educational, Scientific, and Cultural Organization – UNESCO

World Network of Biosphere Reserves –WNBR

CHAPTER I

INTRODUCTION

Ecosystems deliver a wide range of benefits to people. These benefits are known as ecosystem services and include, but are not limited to, fresh water, food, timber, medicines, fertile soils, and leisure opportunities. To meet the increasing human demands, natural environments have been transformed into heavily controlled ecosystems, such as pasture and cropland, and their ecosystem services have been used extensively (De Fries et al., 2004; Foley et al., 2005; Rodríguez et al., 2006). Land use intensification and land conversion are significant drivers of habitat fragmentation, ecosystem service reduction, and biodiversity loss (Foley et al., 2005; Pereira et al., 2012). More sustainable land management and land use techniques may deter further environmental degradation and ensure ongoing provision of ecosystem services.

To direct sustainable land management practices, there is an urgent need for in-depth knowledge on the present and future impacts of land management on ecosystem services. Substantial attempts have been made to enhance the quantification of ecosystem resources and to recognize the importance of ecosystems to human well-being (Crossman et al., 2013a). However, there are still many considerable uncertainty on how ecosystems provide services, how ecosystem services are reliably defined and quantified, how these services interact, and how improvements in land management impact these services (De Fries et al., 2004; Carpenter et al., 2009; De Groot et al., 2010b; Villamagna et al., 2013). The empirical data on the potential of ecosystems to offer a range of ES sequentially is segmented, and there's still a lack of solid scientific backing for incorporating ES into land-use decisions (Turner and Daily, 2007; Nelson

and Daily, 2010; Ehrlich et al., 2012). Even though methodologies for classifying, quantifying, and valuing ES are rapidly improving, implementations of the concept in everyday decision-making procedures remain constricted particularly at the planning level. Nonetheless, systematic considerations of the impacts of spatial planning decisions on ES would be beneficial (Liekens et al., 2013). This advocates for a deeper understanding and quantitation of ES under substitute land management systems (Balmford et al., 2008; ICSU et al., 2008; De Groot et al., 2010a) as well as further development of modeling and mapping tools that metabolize data to aid land management decision making (Nelson and Daily, 2010; Vigerstol and Aukema, 2011) especially in biosphere reserves. Thus, ecosystem services allow local stakeholders to understand ecosystem services' contributions to spatial planning and landscape management.

A biosphere reserve is a community-inclusive concept that aims to promote a balanced relationship between man and nature. They've been established to protect ecosystems, share environmental knowledge, and promote the socially and ecologically sustainable use of natural resources (UNESCO, 2002). The biosphere reserves are divided into three interconnected zones: the core, buffer, and transition area. However, challenges to management and conflict with residents over access to natural resources do occur from time to time in biosphere reserves. The reason for this is that provisioning services, particularly agriculture, is destroying biodiversity and causing disputes between managers and farmers. Furthermore, there are management challenges due to the difficulty of determining and mapping these ecosystem services due to a lack of data availability.

Ecosystem services (ES) are particularly well-suited to the biosphere reserve system because they can help in the monitoring and analysis of ecosystem health, as well as a better understanding of how biosphere reserves support nature and society (Assessing Ecosystem Services in UNESCO Biosphere Reserves). Furthermore, they can capture the benefits of protected land and managed properties, as well as trade-offs and links between these various areas of use.

This research focuses on the Jabal Moussa Biosphere Reserve (JMBR) in particular. JMBR is a unique mountain forest ecosystem with extraordinary geological and biological characteristics that, together with its cultural heritage, have allowed it and its surrounding villages to become part of the UNESCO Biosphere Reserves Network under the MAB programme (A Walk Through Jabal Moussa, n.d.); however, studies show that it's not properly managed and is treated more as a protected area (Karam, 2016). Moreover, the main difficulties and limitations that people have faced in the study of Jabal Moussa are mainly attributed to the lack of data. Due to the lack of forest inventory in JMBR, there's no data on the quantities provided for the different goods and services (Karam, 2016). The lack of data is primarily due to the absence of accurate forest production mapping (Karam, 2016), hence this paper tries to map the ecosystem services in JMBR. In addition, it tries to identify the types of management that are required in different areas and the different values that the biosphere needs to prioritize, such as social, cultural, or health values, to ensure the proper coexistence between man and nature.

Hence, the goal of this study is to map provisioning services focusing on agriculture production in biosphere reserves to assess whether there is a basis for conflict between residents and managers and challenges to the management team. As a

result, this paper attempts to answer the question, "How can mapping food production locations enhance land management decisions in Jabal Moussa Biosphere Reserve to ensure long term ecosystem services provision?"

Maps of the food supply (apples, strawberries, and tomatoes) in Jabal Moussa Biosphere Reserve generated in this paper assisted in identifying unsustainable and incompatible agricultural practices occurring in different areas of the biosphere reserve, and recommendations are provided to improve these practices and make better decisions for the reserve's long-term sustainability.

CHAPTER II

LITERATURE REVIEW

A- Biosphere Reserves

1- UNESCO's Man and Biosphere (MAB) Programme

The discovery of a sufficient balance between the strict preservation of biodiversity and the development of local communities was the subject of many protection studies and discussions that led to the formation of community-based and other participatory approaches to the management of protected areas. In response, UNESCO launched the MAB programme in the early 1970s to provide a scientific framework for enhancing human-environmental relations, addressing issues such as the fair use and protection of natural resources, and ecologically sustainable land use (Batisse 1986; Bioret et al. 1998). It uses the World Network of Biosphere Reserves (WNBR) as tools for knowledge sharing, investigation and monitoring, education, and participatory decision-making. (UNESCO, 2008) The WNBR is a "science-for-sustainability" support network that involves collaboration with an appropriate array of stakeholders, including scientists and local communities (Schultz et al., 2011). UNESCO Member States have been encouraged to develop MAB committees and programs in their own countries and to identify sites where these principles can be implemented. Currently, there are 701 biosphere reserves, as shown in ***Table 1***, including 21 trans-boundary areas distributed in 124 countries (Biosphere Reserves: United Nations Educational, Scientific, and Cultural Organization, n.d.). Since the development of the MAB, the context where the biosphere reserves function has

changed considerably but remains highly interdisciplinary (Francis and Whitelaw, 2004).

Table 1 The distribution of biosphere reserves around the world (Source: Biosphere Reserves: United Nations Educational, Scientific and Cultural Organization, n.d.)

Biosphere Reserves	
Location	Number
12 Arab countries	33
21 Latin American and Caribbean countries	130
24 Asian and Pacific countries	157
29 African Countries	79
38 European and North American countries	302
Total	**701**

2 - What are Biosphere Reserves

Biosphere reserves are regions that contain land, aquatic, and coastal ecosystems. They're internationally recognized regions, retaining their country's sovereignty, chosen by the scientific interest in their biological, environmental, and cultural value, and where socio-economic, human, and conservation activities are established by the inhabitants of these territories to promote sustainability. They're unique sites for exploring interdisciplinary methods to understand and manage interactions and changes between social and ecological systems, including conflict reduction and biodiversity management. They also encourage research and education as well as the exchange of experiences among the different actors living there (Biosphere Reserves: United Nations Educational, Scientific, and Cultural Organization, n.d.). They also aim at reducing poverty and respecting people's culture and cultural beliefs.

3- The Importance of Biosphere Reserves and their Benefits

Biosphere Reserves are an excellent alternative to a harmonious human-nature relationship by recognizing the values that contribute to humanity through natural resources and biodiversity. They help ensure the sustainability of the area by incentivizing the smart use of human and natural resources. The biosphere notion is used as a framework to strengthen and guide projects aimed at improving peoples' livelihoods and ensuring environmental sustainability. (*Importance of Biosphere Reserves,* n.d.) The following are some of the advantages of biosphere reserves:

a. Adoption and implementation of United Nations goals

Biosphere Reserves are a concrete way for countries to adopt Agenda 21, the Convention on Biological Diversity (e.g., the Ecosystem Approach), the UN Decade for Sustainable Development Education, several Millennium Development Goals (e.g., environmental sustainability). (Biosphere reserves, their function and their benefits..., n.d.), and Sustainable Development Goals (SDGs), as shown in ***Table 2***.

Table 2 Case Studies: Connecting Biosphere Reserves to the Sustainable Development Goals (Source: The Man and the Biosphere (MAB) Programme of UNESCO and., n.d.)

Seaflower BR (Colombia)	**1,2,6,7,8,12,13,14,15**		Economic alternatives based in green markets; Implementation of alternative energy
Sierra Nevada de Santa Marta BR (Colombia)	**11,15,17**	11.3. 11.4 15.1 15.2 15.4 17.17	Strengthening of the indigenous governability in the ancestral territory
Pachmarhi BR (India)	**1,2,4,5,6,7,8,10,13,15,17**		Construction of Pond for providing Irrigation facilities to nearby villages
Agasthiyarmalai BR (India)	**15,17**		Multi-Stakeholder Dialogue on the forests of the BR
Nilgiris BR (India)	**15,17**		|Promotion of ecotourism activities
Sundarban BR (India)	2,3,4,6,8,15		Honey collection from Sundarbans forests by traditional honey collectors
Alto Bernesga BR (Spain)	**4,5,8,15,17**		capacity-building; communication and awareness.
Area de Allariz BR (Spain)	**11,15,17**		Waste management projects : Composting island next to urban gardens
Lanzarote BR (Spain)	**11,15,16,17**		Multi-stakeholder governance processes
Montseny BR (Spain)	**11,15,17**		Multi-stakeholder governance processes

Case studies	SDGs	Targets	Themes and/or flagship projects
Aya BR (Japan)	**2, 12, 15**[1]	2.4 12.4	Evergreen forest protection; ecological agriculture
Arganeraie BR (Marocco)	3,5,6, 15		Climate change mitigation; women empowerment; production of argan oil
Oasis du Sud BR (Marocco)	3,6 8,13,15		Project of awareness raising "sauvons nos oasis"
del Odiel BR(Spain)	**12,15**	12.2 12.4 12.5 12.6 12.8	European blue carbon fixation project "Blue Natura".
Omo BR (Nigeria)	1,8,15		Economic alternatives based in green markets
Schorfheide-Chorin BR (Germany)	**7,8,15**		Traditional architecture construction with climate-friendly techniques to safe energy and resource
Mount Hakusan BR (Japan)	2,3,4,5,7,8,10,12,15		Educational activities using the 17 SDGs as tools helped to raise awareness in regional issues
Magaliesberg BR (South Africa)	4,15,16		Preservation of keystone species (leopard)
Tadami BR (Japan)	**8,12,15**	8.9 12.2 12.8	Eco-certification: Labels for the traditional product brand " Capital of Mother Nature Tadami"
Camili BR (Turkey)	1,2,8,12,15		Ecotourism; Beekeeping; Agriculture and Animal Husbandry
La Red Espanola de la Biosfera BR (Spain)	**4,5,8,11,12,15,16,17**		Waste management

b. Conservation

Biosphere reserves protect species, habitats, landscapes, and ecosystems without impacting the people living there. They also act as gene banks to preserve genetic material. Moreover, they contribute to the preservation of a wide environmental heterogeneity resulting from geomorphological characteristics, topography, soil, and microclimate that support different types of vegetation and interactions of plants, animal species, and related ecological processes that are important for maintaining the balance in these ecosystems. Conservation is at the heart of all works and duties in a biosphere reserve, and the region's biodiversity must be well preserved to ensure the reserve's long-term viability.

c. Development

Biosphere reserves guarantee sustainable development, such as social, economic, and cultural development that aim to improve people's well being.

d. Healthy Ecosystems

Biosphere Reserves facilitate the conservation of life-supporting systems; by preventing soil erosion; maintaining water springs; decomposing agents promoting nutrient recovery, and removing contaminants from air and water. (*Importance of Biosphere Reserves,* n.d.)

e. Research and Education

Biosphere reserves at the national level can act as pilot sites to test and illustrate conservation and sustainable development strategies, offering lessons that can be implemented elsewhere (Biosphere reserves, their function and their benefits ..., n.d.). They are places for research on natural resource organization and dynamic movement, including humans. Through research, they enable the restoration of environments impacted by human activity, the identification of species that have vanished, the monitoring of processes of climate change, the search for the recovery of ecosystems and their components, and better decision making.

f. Land-Use Planning

Biosphere Reserves manage participatory land-use planning. All sectorial organizations, landowners, public institutions, researchers, farmers, industries, conservation groups involved in these territories should address disputes and shared

interests and work together to organize the quest for effective land management. Hence, the biosphere reserve focuses on stakeholder collaboration and voluntary participation. They promote local government engagement and encourage the collective search for solutions to social and environmental problems. They are spaces in which sustainable economic practices are created.

g. Restoration

Biosphere reserves restore habitats and ecosystems that have been damaged. (*Importance of Biosphere Reserves*,n.d.).

4 - Biosphere Reserve Principle and Program Progression

The concept of the Biosphere Reserve emerged as a tool for global cooperation, addressing problems and issues related to the interface among environmental conservation, interdisciplinary monitoring and research, and educational primacy in environmental sciences. The biosphere reserve definition, however, has been revised numerous times as of 1971. This has typically developed in three major stages, which are chronologically illustrated below. Such phases are characterized by two main meetings: the 1995 Seville conference that resulted in the essential legislative structure and the Seville strategy, and the 2008 Madrid meeting that resulted in the Madrid Action Plan (MAP). These documents are the key guiding documents of the work system of the MAB to date. The fourth phase is now underway, with the introduction of a new MAB strategy for the years 2015-2025. Owing to the ongoing development of the biosphere reserve principle during the implementation phase of the MAB program, there's a need to establish a framework to help biosphere managers oversee the gap

between principle and action by ensuring that biosphere reserves fulfill their functions (Price, 2002).

1st Phase: From the beginning → the Seville meeting (1971-1994)

Early interpretations of the biosphere reserve term provide a theoretical reference to three key functions, as shown in ***Figure 1***:

1- Conservation: representative habitats with substantial conservation value are integrated into the biosphere reserves.

2- Sustainable Development: the pursuit of sustainable human and economic growth.

3- Logistic support: offering logistical support for scientific study, monitoring, and environmental awareness and training.

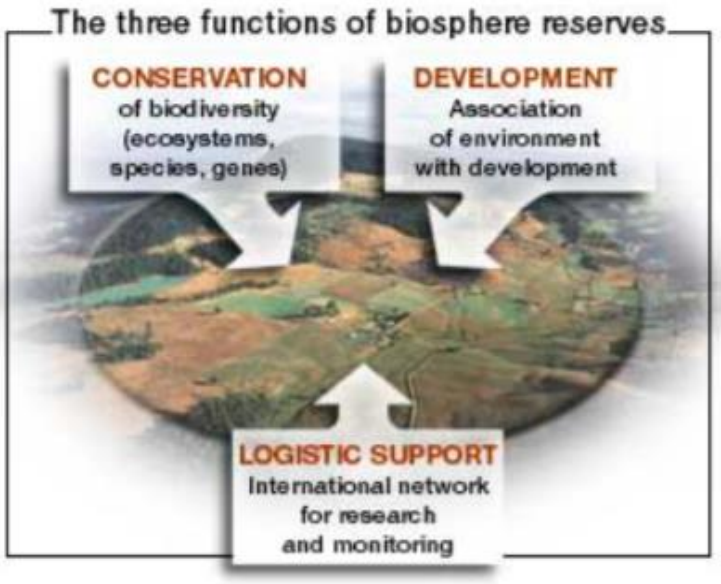

Figure 1: The Three Functions of Biosphere Reserves (Source: Pollock, 2011)

The three functions were associated with three concentric zones within the biosphere reserve: a core region (i.e., a strictly protected area with specific boundaries that fulfills the role of conservation) surrounded by a clearly defined buffer area where only non-destructive regulated activities (e.g., research and monitoring) are allowed (IUCN, 1987), and a broader, versatile transition area where a vast array of sustainable activities (e.g., agriculture) can take place, as shown in ***Figure 2***. While these three functions were stated clearly, the early classification of biosphere reserves by UNESCO was primarily focused on existing protected areas with substantial conservation value and strong research potential (Batisse 1986; Price 2002). This culminated in a "neglect" of the role of biosphere reserves in sustainable development and poor implementation of the three-zone principle till the Seville meeting in 1995 (Batisse 1986; Price 2002; UNESCO 1996). Just 23 percent of biosphere reserves designated between 1976 and 1984 implemented the three-zone scheme, of which 65 percent were designated between 1985-1995, while up to 98 percent of biosphere reserves implemented the scheme after 1995 (UNESCO 2008, 9). Moreover, neither has the Concentric Zone Model been exclusively applied due to contextual constraints (UNESCO, 1996). Following the Rio Summit in 1992 and the adoption by more than 100 countries of the Convention on Biological Diversity, the role of biosphere reserves in sustainable development has been enhanced.

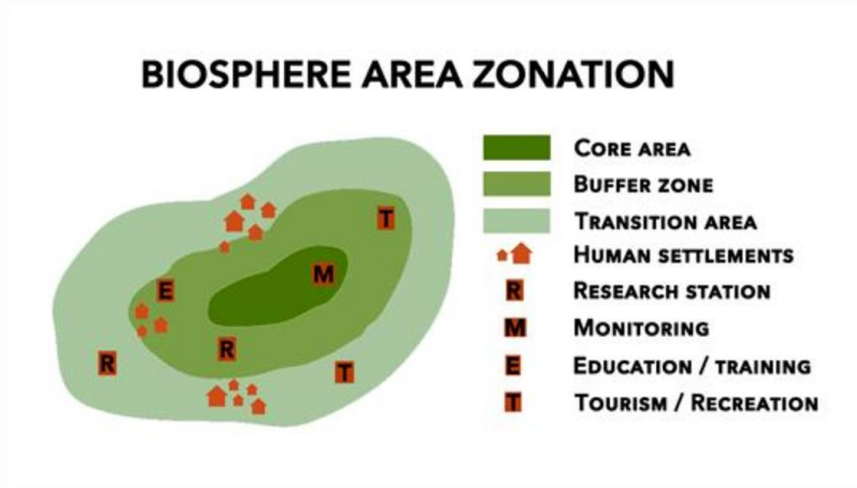

Figure 2: Biosphere Reserve Zoning Model 1: "Three important, concentric zones: strictly protected core zones at the center (dark green), surrounded by buffer zones with low human impact (medium green), which are in turn surrounded by transition zones where more intense development could happen (light green)." (Source: Guevara et al., 2008)

2nd Phase: The Seville meeting → the Madrid meeting (1995-2007)

In 1995, the Seville Strategy and the Statutory Framework (UNESCO 1996) reinterpreted the three-zones scheme in the context of the previous 20 years of practice. As a consequence, the strict concentric model of "three-zones/three-functions" was substituted by the idea of "functional zones," that was more technically relevant, as shown in ***Figure 3***:

1- Core Region: each biosphere reserve can have several core areas that constitute conservation areas secured by national legislation. Such regions would reflect undisturbed habitats and ecosystems of essential species and provide for research, surveillance, and some training.

2- Buffer Region: pervades the core region (s) and offers a buffer for eco-friendly and sustainable activities like basic research, education, and eco-tourism.

3-Transitional Region: one cooperative region that includes core and buffer regions and covers a broader range of human-activities with several stakeholders and organizations interested in their sustainable management.

The Seville Strategy, therefore, marked a move towards more autonomy and convergence of zones and functions. Enhanced harmonization and cooperation between the different zones were necessary by guaranteeing the presence of management resources and organizations (UNESCO 1996). Moreover, selection process, management planning, and periodic review reporting policies have been developed within the context of the new strategy as measures to ensure the effective execution of the three biosphere reserve functions (UNESCO 1996; Price 2002) from which the meanings in Article 3 of the legislative structure have been clarified as follows:

" conservation-contribute to the protection of habitats, biodiversity, and genetic variation; development- promote socio-cultural and ecologically sustainable economic and human development; logistical support-promote demonstration projects, environmental education and training, study and monitoring relevant to global, national, regional, and local conservation issues and sustainable growth (UNESCO 1996, 16).

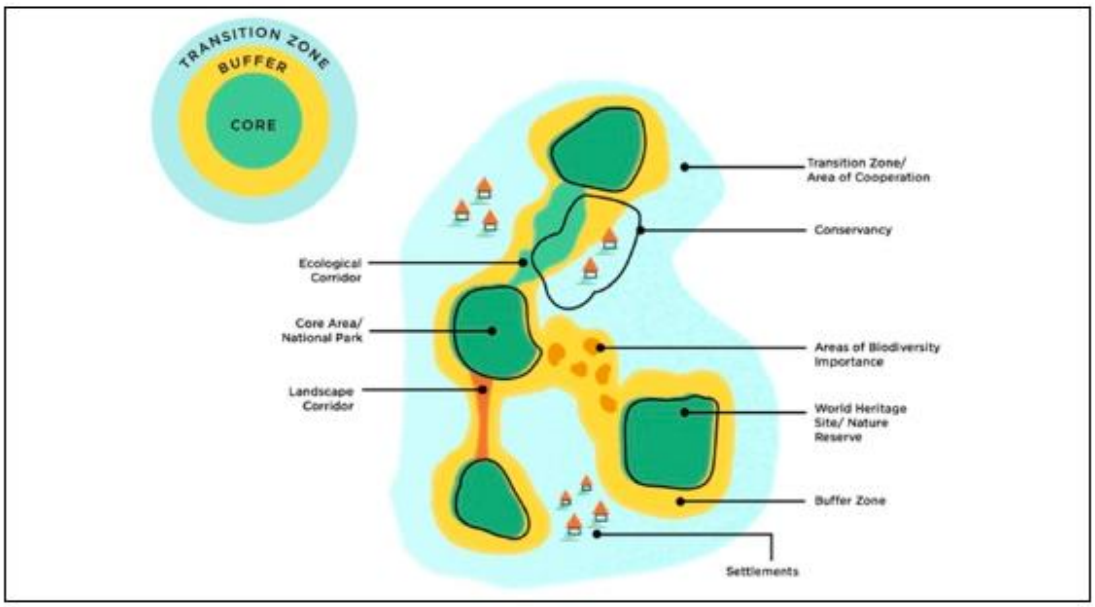

Figure 3: Biosphere Reserve Zoning Model 2 (Source: Pool, 2020)

3rd Phase: Madrid Meeting and Findings (2008-2014)

During the 3rd World Congress, in March 2008, on biosphere reserves in Madrid, the idea of biosphere reserve was introduced as a "learning ground for sustainable development" (UNESCO 2008) with a greater emphasis on development functions and logistical support. Further attention has been paid to the buffer and transition areas and their function in supporting biosphere reserves as model sites for sustainable growth. A new criterion for boundary delineation for the transition area has been developed while growing flexibility in the integration of functionalities has been encouraged (UNESCO 2008). Consequently, the period following the Madrid meeting is marked by UNESCO's tighter criteria for the definition of the biosphere reserve zone and management reporting. On the other hand, more versatility is provided by combining the three functions into the various zones (i.e., each of the three zones will represent the three functions in various degrees).

It's worth noting – from the perspective of MAB evolution – that MAB's role during this time was to "improve and expand cultural and ecological diversity while ensuring human well-being through sound study and cooperation with a sustainable array of stakeholders, also including local people and researchers" (UNESCO 2008).

The meeting culminated in a landmark document called the Madrid Action Plan (MAP), which builds on the strategic goals of Seville and seeks to make the biosphere reserves the leading international sites committed to sustainable growth in the 21st century (UNESCO, 2008). The Strategy identified 31 goals with their

own 64 actions, measures and responsible parties, including four significant themes (UNESCO, 2008): Zonation and Linking Functions to Space (Target 12-14); Science and Capacity Enhancement (Target 15-24); Cooperation, Management and Communication (Target 1-11); and Partnerships (Target 25-31).

4th Phase: Designing a new MAB strategy (2015-2025)

The launch of the new phase of the MAB program was marked by a thorough and final review of the MAP for biosphere reserves conducted by the UNESCO Internal Oversight Service (IOS) in May 2014 (UNESCO, 2014d). The outcomes of this internal analysis offered feedback for the new MAB Strategy 2015-2025 (UNESCO, 2015a) circulated to all MAB National Committees in its final draft on May 4, 2015, and implemented by the International Chamber of Commerce (ICC) 27th Session in June 2015 (Ramadan-Jaradi pers. comm.). The 2015-2025 MAB strategy includes an action plan that can be implemented at the 28th session of the ICC in 2016 (Ramadan-Jaradi pers. comm.).

The latest strategy (2015-2025) offers the WNBR a new strategic direction by positioning the MAB program as a central contributor to UNESCO's general plan for forming scientific research agendas and achieving global sustainability targets (UNESCO, 2015a). More precisely, the MAB program is intended to support UNESCO's sought-after commitment to the promotion of global and regional scientific collaboration in the implementation of the post-2015 development agenda. As a result, the World Network of Biosphere Reserves (WNBR) is now considered to be one of UNESCO's influential instruments to promote the transition to green economies by offering urban technology experimental sites.

The overall mission of the MAB has been updated to accommodate this new strategic direction and is now described as:

"Our goal is to encourage a prosperous future by linking people with nature today. During the next ten years and ahead, the MAB Program will enable the Member States to achieve sustainable development goals by learning from its model network (sites/regions) where development policies and activities and the management of natural resources and biodiversity are discussed and demonstrated; and lessons obtained are harnessed by sustainability research, education and information sharing" (UNESCO 2015a, p.7).

With this viewpoint, four new strategic priorities have been drawn up (UNESCO 2015a, p. 7):

"1. Conserve biodiversity, preserve and improve ecosystem services and encourage the sustainable use of natural resources

2. Contribute to the development of secure, stable and inclusive communities, markets and prosperous human settlements

3. Facilitate environmental research and education for environmental growth

4. Support climate change adaptation and mitigation and other facets of global environmental change."

The revised mission and goals established by UNESCO for the MAB program highlight the role of the biosphere reserves in achieving current global sustainability objectives.

5- Biosphere Reserve Zoning Scheme

Biosphere reserves strive for integrated management of water, land, and living resources by implementing bioregional planning strategies, which integrate conservation with development via proper zoning. (Zoning schemes: United Nations Educational, Scientific and Cultural Organization, n.d.). At the national level, countries can freely define the zones of a biosphere reserve, but they must ensure that the zones successfully combine sustainable resource utilization, conservation, and knowledge creation through collaborative management and integrated zonation schemes. (Zoning schemes: United Nations Educational, Scientific and Cultural Organization, n.d.). As of now, the spatial arrangement of biosphere reserves obeys a nested scheme wherein various land use frameworks and regulations are allocated to zones ad - hoc networks, complicating evaluation of their efficacy. (Lourival et al., 2011)

Zonation is a crucial aspect of a biosphere reserve, but it's also frequently contentious because it spatially prohibits land use for specific applications. (Hedden-Dunkhorst and Schmitt, 2020) As a result, the involvement and participation of different stakeholders, as well as their affirmation of the zonation, is critical to effectively address and fulfill the functions of a biosphere reserve (Pool-Stanvliet et. al., 2018). More comprehensively, concerning a biosphere reserve's double aim of sustainable development and conservation, the question of how management can effectively connect these objectives emerges, particularly in a zoned landscape. (Hedden-Dunkhorst and Schmitt, 2020) A biosphere reserve must employ a strategy of demonstrating the economic value of conservation practices to all the different stakeholders. Ecotourism in the buffer area create jobs and revenue. For instance, preserving fish breeding grounds increases long-term fishery gains, and

simple composting methods improve agricultural yields (Hedden-Dunkhorst and Schmitt, 2020). Operations that link stakeholders' requirements to the biosphere reserve's vision improve trust and understanding in the reserve. However, as we will see in our case study of Jabal Moussa, maintaining these zones is extremely difficult, raising the question of whether exclusion zones should be reinstated for the sake of wildlife conservation, or whether development and conservation can coexist.

The zonation method can be an efficient tool for managing a landscape's "multi-functionality" (Sayer et. al, 2013) and addressing the corresponding trade-offs "in a spatially explicit and ecosystem-driven manner that reconciles stakeholders' multiple needs, preferences, and aspirations" (Sayer et. al, 2013). Nevertheless, to produce positive results, the zonation method must include an intensified negotiation process with all of the relevant stakeholders; it must align the goals of the biosphere reserve with preexisting land-use practices and development plans, as well as tackle the dynamic nature of land-use practices in a landscape over some time. (Hedden-Dunkhorst and Schmitt, 2020) When incorporating a zonation concept into preexisting land management strategies and traditional methods in BRs, it doesn't have to be at odds with preexisting spatial disciplines; rather, the designation of a BR could indeed scale up subsequently integrated management endeavors and achieve greater exposure for the region. (Hedden-Dunkhorst and Schmitt, 2020) Furthermore, a BR can be incorporated into local modes of resource management that already exist. Substitute natural resource management strategies (i.e. Community-based natural resource management (CBNRM)), on the other hand, can be incorporated into, and contribute to, a larger landscape's management efforts.

However, conflicting land-use aspirations of different stakeholders inevitably exist throughout a landscape. However, incompatible land ambitions of various stakeholders are unavoidable across a landscape. Identifying and resolving these disputes may become a primary goal of landscape management (Sayer et. al, 2013). Engaging key stakeholders early on during the zonation procedure is a feasible approach to achieving a shared understanding of the zonation plan. To persuasively assert the value of a landscape idea, stakeholder engagement must be context-sensitive. The landscape idea, for instance, might be clarified using different models. As a result, stakeholders will have a better understanding of the interconnected impacts, for example, conservation and wildlife recuperation in one area may lead to economic benefits in another via ecotourism (Hedden-Dunkhorst and Schmitt, 2020). Finally, the temporal aspects of land use demand are as important as the multiple spatial land-use processes in a landscape at any particular time. Changing environmental and economic demands, on the other hand, may necessarily require a reassessment of a zonation strategy. In this situation, UNESCO's periodic review procedure can aid in the participatory rezoning of the pertinent landscape in the framework of BRs.

B- Biosphere Reserve Management

1- Biosphere Reserve Management Objectives, Aims, and Importance

Four main management objectives are implied in the concept of the biosphere reserve, which are: (1) conservation of habitats (i.e. providing global protection of genetic resources), (2) logistical cohesion and synchronization (i.e. interconnected research and monitoring facilities) (3) sustainable economic and human development (i.e. conservation through the development of a wide range of economically feasible

choices for rural folks living near the reserves) (Batisse, 1980, 1990) and (4) climate change mitigation and adaptation.

It's important to manage the biosphere reserve and make good decisions to be able to perform its functions. A wide range of data on diverse facets of the biosphere reserve, such as the status of protected areas and species, research and monitoring results, provincial plans, economic and demographic information, must be made available for appropriate management. There must be sharing of information between different stakeholders and organizations involved in the planning and management of any biosphere reserve territory. Adequate flow of information and its exchange as well as the mobilization of knowledge are the ultimate prerequisites for decision-making and sound management at all levels. Good management practices bring together a wealth of knowledge, scientific research and expertise to link socio-economic development and biodiversity preservation to human well-being that guarantees the proper coexistence between man and nature.

2- Components of Successful Biosphere Reserve Management

There are eight components to consider as key criteria for the successful management of a biosphere reserve. It must be acknowledged that the components aren't mutually exclusive, but are complementary. “The eight components are (UNESCO Office, Jakarta Publications, n.d.):

a. Participatory Platform

Biosphere reserves must act as a participatory platform that engages and connects various stakeholders, such as communities, youth, and businesses. This platform aims at exchanging information, contributing to decision-making, improving

cooperation by easing dialog among different stakeholders, and generating new solutions to local problems, development initiatives, and joint ventures. The platform can come in various names and forms – a committee, a council, a forum, a community round-table, or a conference. Its mechanism can be enhanced through the use of online or physical media like the biosphere reserve center, depositories, websites, blog posts, and other social media channels. Social media is an additional feature that will strengthen cooperation and the sharing of information.

b. Policy Integration

Biosphere Reserve Management must share a common goal and must be supported by all interested parties. Most of the biosphere reserves include core areas and buffer zones safeguarded by authorities and national legislation. These adjustments are often separate from the transition area and, as a result, policy aggregation or poor communication may happen. In this respect, an integrated management plan is required to incorporate visions, goals, activities, policies, and objectives between several biosphere reserve stakeholders and to provide a roadmap for the management of a biosphere reserve. Such a strategy should take into consideration the framework of traditional, local, and scientific knowledge.

c. Partnership and Networking

Biosphere Reserve Management must build and sustain alliances and networking between all partners to support any project execution. By entering into partnerships, Biosphere Reserve Management can educate and inform interested parties on the importance of integrating preservation and development, and also opportunities

to increase and optimize private sector financing and try to obtain other sources of funding. Partnerships may be established with government entities, other biosphere reserves, private sectors, youth communities, and academic institutions. Eco-labeling projects are an indication of such partnerships in the private sector. The creation and implementation of strong international, national, and local networks is essential in exploring even further possibilities for partnerships.

d. Periodic Review

Biosphere Reserve Management must use periodic reviews to ensure the quality and efficient operation of the biosphere reserve. MAB National Committee and Biosphere Reserves are recommended to conduct a voluntary periodic review roughly every one to five years. Aspects for volitional periodic review may indeed be streamlined to suit local capacity, demands, and resources. Stakeholder involvement and cooperation (e.g., university, other organizations, academic communities, etc.) are key factors in assessing and monitoring activities.

e. Strengthen Administration

Professional development is critical in strengthening the management of the biosphere reserve. Administrative resources (including human resources, budget, expertise, and so forth.) must be increased to ensure that the objectives of the biosphere reserve are properly implemented. In order to improve professional development, Biosphere Reserve Management is invited to participate in pertinent training programs and workshops provided by different biosphere reserve networks (like EABRN,

SeaBRnet, WNICBR, etc.) and many other MAB external professional development possibilities.

f. Legal Recognition

Biosphere reserves must have legal recognition that provides a suitable level of legitimacy for the establishment of clear governance structures for the biosphere reserve, cross-sectorial cooperation, and policy assimilation. A well-integrated and appropriate legal recognition will boost awareness among stakeholders, partnerships, and public sector support.

g. Promoting Existing Framework

Biosphere Reserve Management must endorse, embrace and implement existing frameworks, plans and indicators, such as the new MAB Strategy (2015-2025) and the Lima Action Plan. Other applicable UNESCO reports and SDGs and indicators are also useful for more references.

h. Strategic Dissemination of the Framework

Biosphere Reserve Management must incorporate the Standard Framework into the nomination process or the ten-year periodic review process. This could be completed on a voluntary basis at the state level. MAB National Committees could incorporate the Standard Framework into the pertinent national guidelines and perhaps other reports. In this regard, it may even be effective to use a recognizable name for the framework to make it widely available, such as the Seville Strategy, Kyoto Protocol, and Lima Action Plan.

To ensure the successful management of Jabal Moussa, all stakeholders, including the community, non-governmental organizations (NGOs), ministries, local municipalities, scientists, and youth, must participate in decision-making for the benefit

of the biosphere reserve. For any activity to be implemented successfully, all stakeholders must form strong partnerships and networks. By forming such alliances, Jabal Moussa's management can enlighten all the stakeholders about the importance of integrating development and conservation, and also pursue possibilities to raise funding from different sources. Additionally, administrative resources such as human resources, budget, expertise, and many others must be increased in order to effectively execute Jabal Moussa's goals. Furthermore, national authorities and legislations protect the core and buffer areas of Jabal Moussa, but not the transition area, resulting in policy fragmentation and the urgent need for an integrated management plan. Finally, a periodic review of Jabal Moussa every couple of years can help retain its proper functioning in response to local needs; Jabal Moussa must also adopt the new MAB Strategy (2015-2025), as well as the SDGs.

3- How to Properly Manage a Biosphere Reserve

A biosphere reserve's management system needs to be open, changing, and adaptive to better respond to external economic, social, and political pressures that would impact the area's ecological and cultural values. Hence, it is necessary to establish an effective governance structure (e.g., committee or board) to organize and coordinate all the activities of all the stakeholders involved, each within their mandate and expertise (Biosphere reserves, their function and their benefits ..., n.d.).

While the biosphere reserves are meant to be locally-driven, the nature of individual reserves varies significantly across sites and countries. A mandate and vision are selected along with the mechanisms that decide who may be involved and how, when, and why to hold meetings, and what roles and responsibilities to be allocated to

participants. Several actors can sit on the board, including those representing public authorities, NGOs, academics, private interests, and local inhabitants (Dogse, 2004).

For example, Canada's biosphere reserves are typically collaborative initiatives involving multiple groups within a common environment to gain international recognition, putting an unprecedented focus on experimenting with bioregional approaches to conservation and sustainable development in these regions (Pollock, 2011).The practical application of the concept of the biosphere reserve requires ongoing community involvement of different types, depending on the process or activity in question (Pollock, 2011).

A collaborative, multi-stakeholder approach to managing biosphere reserves is one aspect that appears to be widely shared among many of the world's biosphere reserves. Even though many European countries have established top-down approaches (i.e., national to local management and administration structures) in the MAB programme, many biosphere reserve managers themselves have developed cooperative relationships among and between regional governments, educational and scientific institutions, and entrepreneurs and local business leaders (Pollock, 2011). Stoll-Kleemann and Welp's (2008) research on biosphere reserves in seventy-six countries has shown that the majority acknowledges that local involvement is fundamental to the biosphere concept. Nevertheless, not all members of the Biosphere Reserve Network have taken a participatory approach to management. At the EuroMAB Network conference, following a presentation entitled "Local Participation in Biosphere Reserve Management," those firmly in favor of multi-stakeholder governance structures were questioned by those who jumped up to their feet and called out, "But how can we trust

local people to make such important choices about sustainable development?" (Pollock and Whitelaw, 2005)

Moreover, biosphere reserve managers, who have the task of promoting sustainable development, need to address the region in a comprehensive way, not just the ecosystems protected by the law. Managers must address abiotic aspects (water, soil, climate and the landscape as a whole, etc.), local communities (knowledge, traditions, cultures, heritage, etc.) and their practices (agriculture, forestry, livestock breeding, fishing, tourism, etc.). Managers also need to take different actions at different levels, for example: protecting native wildlife, improving the water cycle, advertising agricultural commodities, guiding and teaching local communities, and monitoring the environment. Biosphere reserve managers must work in teams in order to bring together a wide range of knowledge and skills. They have to act as moderators, not rangers. Managers must maintain biosphere reserves afar from their initial nomination. Starting with a project is often a lot easier than maintaining momentum in the longer term. Often the ones who launch a biosphere reserve aren't the best people to manage it for a long period of time.

Moreover, financial resources are often easily and quickly available during the beginning of the initiative, but not necessarily available in the long run. No matter what the context is, the biosphere reserve management is primarily all about empowering local communities and not constraining and limiting them. Biosphere reserve managers must plan ahead to identify future changes in nature, climate, society, and the economy. They need to incorporate all types of knowledge into such planning. Together with other stakeholders, they must lay down this planning into management plans and consensus strategies. They need to enforce these plans through intervention

strategies and fundraising. Managers need to recognize whether unforeseen developments are opportunities or threats, if a mutually consensual planned action plan is a defense against threats, or if new developments are actually enriching. They must consult extensively, while still being able to respond quickly as needed.

4- Drawbacks in the Management of a Biosphere Reserve

Many stakeholders, such as local and national authorities, NGOs, landowners, and communities, have been active in the management of a biosphere reserve. Thus, except in cases where there's one key managing organization (e.g., NGO), management depends more on participatory approaches among stakeholders. The job of the biosphere reserve manager is more focused on showing the benefits of implementing the Biosphere Reserve principle and promoting the management process via dialog among all actors. However, there's a considerable regional disparity, while biosphere reserve managers typically support equitable conservation despite crucial implementation barriers. The phase of participatory conservation poses new risks for the successful management of the biosphere reserve, as the desires of different stakeholders aren't compatible with a predetermined understanding of sustainable growth (Stoll-Kleemann et al., 2010).

5- Local Governance of Biosphere Reserves

A specificity of biosphere reserves is the variety of stakeholders interested in and influenced by their formation and management. Further than the institutional arrangements under UNESCO that include a general institutional and governance structure, the real governance of the biosphere reserves relies on, and interacts with, several layers of strategic and legislative structures (international, regional, sub-regional, national) (Stoll-Kleemann, 2008). It's therefore of critical importance that

"coordination of biosphere reserves be regarded as a versatile co-existence with other modes of control and government" (Stoll-Kleemann, 2008). The complexity of the biosphere reserve governance model was identified as a source of weakness in the effective implementation of the Biosphere Reserve principle because of increased pressure on biosphere reserve management to align biosphere reserve goals and priorities with international, regional, and local development agendas and governance policies (Schliep, and Stoll-Kleemann, 2010). Regional and local features of governance systems may have a major effect on the performance of biosphere reserve management. For example, political support from national and local authorities plays a significant role in obtaining funding for biosphere reserve management, which is also a major obstacle to successful biosphere reserve management and may be the source of many major conflicts. Other facets of governance, such as national conservation policies and political stability, have been reported to have a major effect on the implementation and performance of biosphere reserves (Stoll-Kleemann, 2005).

6- Biosphere Reserve Funding

The funding level depends on the nature and scope of the undertaken programs and activities. Perhaps there is no need for additional funding: current budgets can be matched to achieve common goals. Governments, industries, tour operators, charitable foundations, organizations for research funding, and local municipalities can all help. Continuous government support–albeit only technical and moral –guarantees good connections with national policy and sustainability-related international efforts. In order to initiate regional efforts, UNESCO can provide guidance and sometimes seed funds; these can help facilitate initiatives and set up sustainable financial structures (Biosphere reserves, their function and their benefits ... , n.d.).

Biosphere reserves, which are areas for sustainable development, embody the concept of synergies between nature and people. The notion of ecosystem services that connects human well-being and biodiversity, is well-known today; however, its implementation into real management practices is still unbalanced. (Hugé et. al., 2020) It's critical to learn about the provision, utilization, and patterns of ecosystem services in biosphere reserves in order to ensure their international management transition for the better. (Hugé et. al., 2020)

C- Ecosystem Services

1- What are ecosystem services

Ecosystem services are the indirect and direct contributions provided by the environment, identified as natural capitals, that support human life and well-being Ecosystem services - nature's benefits; n.d.). ES are categorized into four groups, as shown in figure 4, and include: provisioning services such as food (agricultural crops, grass-harvested berries or fish captured from an ocean or lake) and water supply; regulating services such as flood control, drought protection, land erosion, and disease prevention; supporting services such as nutrient cycling and soil development; and cultural services such as spiritual, recreational, educational, social and other non-material benefits. (MEA- Millennium Ecosystem Assessment, 2005) Provisioning services are often referred to as goods and services because people consume them. Supporting and regulating services are usually undervalued because they are indirectly beneficial to people, but they are extremely important. For example, if we had no decomposers in the soil, such as earthworms, fungi, and bacteria, organic matter from dead leaves and animals would accumulate, and there would be no recycling of carbon and nutrients. Such services are considered crucial because they support the capacity of

the ecosystem to provide other services that benefit people more directly from. Soil formation, for example, is not essential to people in and of itself, but without it, farmers would rapidly lose their ability to produce enough food such as trees and vegetables. As for physical, mental, and emotional well-being, cultural services are also necessary. They are linked to our understanding of the environment around us. It can be as easy as a public park where people enjoy walking and taking part in leisure activities to relax and take some time outdoors.

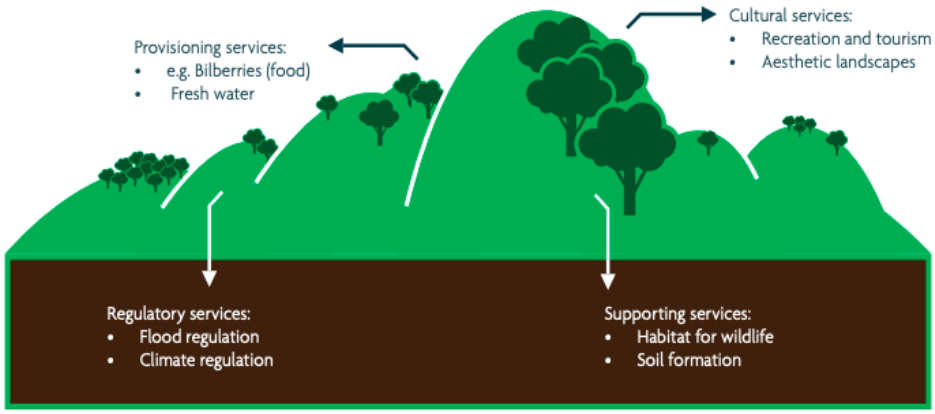

Figure 4: Examples of ecosystem services offered by upland regions (Source: IES, 2013)

2- The Benefits of Ecosystem Services and Their Roles in Biosphere Reserves

Ecosystem services are instruments used globally for environmental management that connect people with nature; they're used for decision-making and for building a shared vision for all biosphere reserves; they're also important for achieving SDGs (Assessing Ecosystem Services in UNESCO Biosphere Reserves). Over the years, human activity's impacts and complexities have evolved and increased. Such developments have had various impacts on community health and well-being, contributing to two phenomena. The first is that ecosystems have been changed, causing irreversible biodiversity loss leading to a reduction in the roles and services of

the ecosystem. The second is that, besides considering nature only at the functional level, we're slowly separated from it and thus have a harder time grasping the consequences of environmental destruction on our lives.

To persuade decision-makers that it is crucial to slow down the deterioration of natural environments on a regional level, the idea of ecosystem services was put forward; this concept facilitates the understanding of the value of several diverse contributions for the well-being of individuals that arise from natural environments.

It’s important to understand the roles ecosystem services play in biosphere reserves so that they can be preserved and restored if necessary. This is particularly necessary when people make decisions about ecosystem protection or exploitation. Numerous researchers are trying to provide empirical data on the environment and biodiversity economic value (Kermagoret and Dupras, 2018). They aim to build a compelling case for sustainability by incorporating the monetary value of biodiversity and the advantages they offer to the existing instrument of economic measurement; however, it is not always possible to apply a monetary value to ecosystem services. Ecosystem services are, therefore, an interesting tool for:

1- raising awareness of the importance of biodiversity and developing a closer relationship between man and nature to encourage the conservation of the natural environment for the present and future well-being of communities;

2- providing a positive alternative to alarmist discourses on environmental damage;

3- proposing a positive view of the region and the future in which people and communities want to participate and invest in.

Challenges like land degradation and climate change make it even more crucial to study ecosystem services. The UN introduced the Agenda 2030 SDGs in September

2015. The SDGs stress the need not only to concentrate on economic growth but also to incorporate environmental and social aspects into resource management and decision-making. The seventeen SDGs illustrate the need for improved environmental conservation in order to achieve some of the primary goals such as SDG 1 and 2: ending poverty and ensuring food security (Vasseur et al., 2017).

The UN, UNESCO, and IUCN have all proposed in recent years that biosphere reserves can be viewed as model sites for learning how to implement and assess SDGs because periodic reviews enable them to measure changes relevant to SDGs over time directly. The main reason for this is that biosphere reserves lead to developing new ways of thinking and explaining how people can live sustainably, in harmony with nature, and by being ecosystem services stewards in their biosphere reserves.

Ecosystem services also play an important role in the global climate change context as they help local communities minimize their vulnerabilities and adjust to climate change through what is known as ecosystem-based adaptation (IUCN, 2009 and The World Bank, 2009). For instance, the IPCC explicitly acknowledges the relationships between climate change and biodiversity loss (i.e., biodiversity loss is considered a fundamental threat to climate-related issues) and how ecosystem services contribute to climate change mitigation as well as adaptation (IPCC, 2012, 2014). Ecosystems eliminate and store carbon from the air. Terrestrial ecosystems absorb approximately 3 billion tons of carbon dioxide /year via net growth, accounting for 30% of global emissions (Canadell and Raupach, 2008). In this sense, any climate change adaptation plan implemented at the local or regional level should be based on ecosystem services inside biosphere reserves (BAWG, 2018).

According to Dee et al. (2017): The Biosphere reserves' unique structure allows them to offer a range of ecosystem services. The three-zone layout helps to provide a variety of services, roles, and contributions. Some ES are primarily supported by protected areas (for example, carbon storage or recreation), while others are primarily supported by working areas (for example, agriculture or productive forestry), and still others are promoted as intermediate areas (e.g., wildlife protection, nutrient regulation, or eco-tourism). It's critical to remember the complex ways in which ecosystem services interact on a broader scale. Some ecosystem services, such as water purification from a wetland in the core area, may provide services to other areas when viewing the biosphere reserve as a whole system. The border between the zones is not a real boundary as far as ecosystem services are concerned, and ecosystem services have an impact beyond the boundary of the biosphere reserve. Approaches for testing ecosystem services in biosphere reserves can vary considerably. Based on the goals and objectives of the biosphere reserve, ecosystem services in the three zones may need to be evaluated separately or together. It is best to assess ecosystem services through the lens of the biosphere reserve's goals and objectives rather than attempting to capture all of the ecosystem services in each area. While it would be interesting to evaluate all of the ecosystem services, it's typically not feasible unless an extensively detailed research project is carried out.

Knowing the roles that ecosystem services play in biosphere reserves is important to protect them and to restore them if necessary. Mapping ES has several advantages, including data that can be used to calculate net future losses or gains, as well as incorporating this data into the spatial-development procedure. Mapping ES is critical for understanding how ecosystems lead to people's well-being and for

supporting policies and management practices that affect natural resources This is particularly important when biosphere reserves work on managing or exploiting ecosystems in any of the three zones with other stakeholders. A forest next to a river should be cut, for instance, to build a few new houses in a suburban subdivision? Understanding the scope of the services provided by the forest, such as buffering against storms and floods, mitigating air and noise pollution, extreme heat reduction and carbon storage, and being attractive and pleasant by residents and visitors (e.g., hikers), will help involve all stakeholders and inform shared decision-making. Ultimately, the decision would depend on the area where the forest is situated and the right owners concerned. Comprehending what's in a biosphere reserve's most important ecosystem services, however, can educate and inform decision-makers significantly. Biosphere reserves also need to recognize the rights of local people, and therefore ecosystem services should consider cultural practices and traditional knowledge as well as the right to be consulted. Nonetheless, local people carry a wealth of knowledge and expertise that contributes significantly to the understanding of our natural environments and in the evaluation of ecosystem services.

D - Mapping and Modeling Ecosystem Services

1- What exactly are maps and models

Maps and models are effective tools for understanding, quantifying, and visualizing the spatial distribution of ES and for communicating this info to decision-makers (Kareiva et al., 2011; Martínez-Harms and Balvanera, 2012; Crossman et al., 2013b). Mapping is a method of collecting and visualizing geospatial data. The maps show certain characteristics of the region visually (“MAPS”, 2013). Maps are used in

this thesis to visualize the properties of ecosystems and the distribution of ES. The spatial mapping of land management is much more challenging because it involves a variety of activities with both a temporal and a spatial aspect.

A model is a simplified and abstract depiction of the real world. It is used in order to understand a certain element of reality (“MAPS”, 2013). Modeling is the simulation and representation of biophysical or socio-economic structural processes by integrating particular system components and parameterizing their behavior and relationships (“MAPS”, 2013). Which and how the elements are combined depend solely on the intention of the visualization and simulation (“MAPS”, 2013). Simple models, in this thesis, have been developed and implemented to measure the availability of ES by establishing links between land use and ecosystem characteristics, and the amount of ES provided. Also, models are being used to evaluate the effect of various scenarios and to compare and project the effects of possible future changes in land management and the intensity of land use. Scenarios describe reasonable and often truncated future pathways, and they're commonly used to examine the effect of environmental and socio-economic changes and the impact of various policies (MA, 2003).

2- Trends in Publications on Ecosystem Service Mapping and Modeling

In the last two decades, the number of publications on ES mapping and modeling has increased significantly, as identified by keyword search in the Scopus database for the time frame 1992 till 2012 (Petz, 2014). Scientific interest in this topic is growing, and it is not only growing in the scientific community, but it is also beginning to grow in the general public's consciousness. Moreover, modeling studies have exhibited a strong increase in comparison to mapping studies. The number of

modeling studies published in 2012 was more than twice the number of the mapping studies (Petz, 2014). Relatively few studies include land management and just a dozen studies incorporate land management with ES modeling or mapping, but this could be due to the diverse nature of the land management activities and associated terms that have led to an under-representation of land management studies (Petz, 2014).

The implementation of ES in everyday decision-making procedures remains constricted especially at the planning level. Nevertheless, systematic considerations of the impacts of spatial planning decisions on ES would be beneficial (Liekens et al., 2013). This advocates for a deeper understanding and quantitation of ES under substitute land management systems (Balmford et al., 2008; ICSU et al., 2008; De Groot et al., 2010a) as well as further development of modeling and mapping tools that metabolize data to aid land management decision making (Nelson and Daily, 2010; Vigerstol and Aukema, 2011), especially in biosphere reserves. As a result, this study attempts to map and model ES (i.e. fruits and vegetables) in Jabal Moussa Biosphere Reserve, as detailed in Chapter 5.

3- The Use of Spatial Scales in Mapping and Modeling Ecosystem Services

Social and ecological phenomena function on a variety of scales, in time and space (MA, 2003). Scale is described as "both the limit of reconciliation where phenomena are distinguishable and the magnitude to which phenomena are characterized over space and time " (White and Running, 1994). Ecosystems function on a spatial scale from land areas, to ecosystems, to landscapes, and global regions. They also function on a temporal scale, from seconds to minutes, to weeks, to hours, to days, and hundreds or thousands of years. Organizations and the use and production of ES are evident throughout the spatial scale (Hein et al., 2006; Balmford

et al., 2008; Fisher et al., 2009). Land management usually happens locally but is restricted by social and economic aspects like international and national markets, organizations, and government regulations (Hein et al., 2006). The evaluation of land management and its impacts should therefore be carried out at various levels of spatial scales.

Mapping and modeling methods are used at different temporal and spatial scales, based on the nature of the issue being analyzed and the scale of the study. Many current studies have mapped out the supply of numerous ES globally (Naidoo et al., 2008), continentally (Schulp et al., 2012), nationally (Egoh et al., 2008; Bateman et al., 2010), or sub nationally. Landscape-level models fit seamlessly into local strategic and spatial planning, unlike global models that offer info on global patterns and trends and can facilitate international policy-making or comply with international science-policy evaluations.

Ecosystem services like pest control, pollination, and recreation, typically function at the landscape scale. The impacts of land use and land cover on the spatial variability of ES have been extensively studied at the landscape, catchment, and regional level in several parts of the world, such as Europe (Willemen et al., 2008; Burkhard et al., 2012; Petz et al., 2012), China (Bai et al., 2011; Wu et al., 2013), and Africa (Egoh et al., 2008; Swetnam et al., 2011; Leh et al., 2013). Landscape-level mapping and modeling methods usually mimic few services and concentrate on a temporal and spatial scale that's relevant to specific policy issues (Nelson and Daily, 2010).

Very few other studies have mapped or modeled land use, land cover, and land management on a global scale (e.g., Ellis and Ramankutty, 2008; Van Asselen and

Verburg, 2012). Food provision, carbon sequestration, climate regulation, and water regulation are the primary ES to be studied at a global scale (Naidoo et al., 2008). Pollination, disease regulation, and pest control are seldom included in global ES studies since they function locally (IEEP et al., 2009). The lack of understanding of processes is yet another barrier to integrating specific services into global models and science-policy assessments, such as disease and air quality regulation (IEEP et al., 2009). A few global models are capable of assessing the effects of environmental and economic variables on natural resources, which include ES (e.g., Global Unified Model of the BiOsphere (GUMBO) (Boumans et al., 2002), IMAGE-GLOBIO3 (PBL, 2006), and G4M (Kindermann et al., 2006). The MA (2005c) had used already published, individual complex models to measure possible effects of global change on numerous ES (Nelson and Daily, 2010). Alcamo et al. (2005) and Naidoo et al. (2008) have associated sector-based international models to better understand the interaction among hydrological as well as other environmental processes and ES. The Integrated Model to Assess the Global Environment (IMAGE) (PBL, 2006) is among the few international models to describe the environmental effects of socio-economic advancements. IMAGE is often used to support foreign policy formulation in conjunction with the Global Biodiversity Modeling Framework (GLOBIO3) (Alkemade et al., 2009). IMAGE-GLOBIO3 output values have been used for environmental and biodiversity perspectives (IEEP et al., 2009; Secretariat of the Convention on Biological Diversity, 2010) and also for the initial mapping of ES on a global level (Schulp et al., 2012).

However, many other studies focus on a local level, and more specifically on a particular landscape or catchment area (IEEP et al., 2009; Egoh et al., 2012; Martínez-

Harms and Balvanera, 2012). In the following paragraph, we will go over the ecosystem services that have been mapped and modeled in these studies.

4- Which Ecosystem Services are Mapped and Modeled in Different Studies

The study results of IEEP et al. (2009), Egoh et al. (2012), Martinez-Harms and Balvanera (2012), and Crossman et al. (2013b) demonstrate the ampleness of research on specific ES. On average, about only 4 to 5 distinct ES are mapped and modeled for each independent study. The variety of services analyzed is focused on either the local significance of the service or on the expertise and data availability (Eppink et al., 2012). Regulating services, which include water and climate regulation, and carbon sequestration, are by far the most ones regularly studied, then comes provisioning, habitat support, and cultural services (Egoh et al., 2012; Martínez-Harms and Balvanera, 2012; Crossman et al., 2013b). Medicinal resources, air quality and disease control, traditional knowledge, and spiritual and educational values are rarely studied. Services that are related to freshwater (e.g., water supply and flood control) and carbon sequestration have received great attention in both practical and scientific applications (Vigerstol and Aukema, 2011). They're also among the few globally mapped ES (Naidoo et al., 2008).

This paper specifically maps and models food provision ecosystem services at the local level in order to improve land management decisions in Jabal Moussa Biosphere Reserve to ensure long-term sustainability.

5- Sources of Data and Mapping and Modeling Methods

Prior to mapping and modeling ES, data is required. Datasets could be either primary (i.e., collected or measured field data) or secondary (i.e., modeled or literature-

based data). Primary data provide a more precise assessment of ES (Eigenbrod et al., 2010). Primary data, particularly spatially explicit data, often aren't available and this restricts ES research, which is why literature-based or estimated geospatial data are frequently used (Eigenbrod et al., 2010; Martínez-Harms and Balvanera, 2012; Seppelt et al., 2012). Primary data often aren't easily accessible for larger spatial scales and are thus used primarily in local and landscape-level research. International or national data that is available usually only cover the regulating and provisioning ES (Egoh et al., 2012). Secondary (pre-existing) data, rather than primary data, is used to map ES in this paper. Biophysical data (i.e. LULC variables and InVest) are utilized.

Current evaluations and models of ecosystem service cluster studies use a variety of approaches (Eppink et al., 2012; Seppelt et al., 2012). These approaches are classified into 4 methodological groups according to studies that were done by Balmford et al. (2008), IEEP et al. (2009), Eigenbrod et al. (2010), and Martínez-Harms and Balvanera (2012). Moreover, these approaches are described using the recent scientific literature.

The four methodological groups are (1) proxy-based methods or lookup-tables, (2) statistical models, (3) causal relationships, and (4) biophysical models. They vary in the level of complexity and data requirements (Balmford et al., 2008; IEEP et al., 2009; Egoh et al., 2012; Martínez-Harms and Balvanera, 2012). They use several different mathematical techniques like dynamic models, regression analysis, and geographic information system (GIS) that could be implemented to various spatial scales (Balmford et al., 2008; IEEP et al., 2009; Egoh et al., 2012; Martínez-Harms and Balvanera, 2012).

1- ***Proxy-based methods*** that use expert or literature estimates of ES tied to specific types of land use or land cover are the most frequently used approach for mapping ES (IEEP et al., 2009; Egoh et al., 2012; Martínez-Harms and Balvanera, 2012). Land cover based proxies allow users to map ES rapidly in areas where primary data are sorely missing. Also, proxies generalize info, minimize spatial accuracy, and restrict the knowledge of environmental processes (Eigenbrod et al., 2010; Rounsevell et al., 2012). Carbon sequestration often is derived from land use or land cover, at both the landscape-scale (e.g. Raudsepp-Hearne et al., 2010; Bai et al., 2011) and the global-scale (Naidoo et al., 2008). Other widely used proxies for ES include vegetation, soil, and nutrient-related factors (Egoh et al., 2012).
Regulating services often are approximated using database systems (e.g., Food and Agriculture Organization of the United Nations, FAO) and remote sensing and topographic info (Martínez-Harms and Balvanera, 2012). International estimates of food, livestock, and timber production are often drawn from FAO statistics (IEEP et al., 2009).

2- ***Statistical models*** offer the most precise info on ES where primary data is accessible. They use regression analysis or statistical correlation to deduce the availability of ES across space contingent on recorded field-data from various environmental and biophysical variables (Martínez-Harms and Balvanera, 2012). For example, Willemen et al. (2008) used a regression analysis to map the data on plant habitat and tourism. Statistical models could be used to tie biophysical processes to social factors like expectations and perceptions upon which the cultural services depend

(Sherrouse et al., 2011; Daniel et al., 2012). Statistics offer the foundation for monitoring and quantifying uncertainties in the assessment of ES (Smith et al., 2011). Statistical models measure the correlation not inherently the causality. The use of statistical relationships for circumstances outside the existing data framework may indeed generate inaccurate data. Statistical models are very seldom used globally because primary data is limited at this level.

The SolVES is a GIS tool that evaluates, maps, and quantifies perceived social values of ecosystems, and it also utilizes statistical models (Sherrouse et al., 2011). Other examples include Maxent (Phillips et al., 2006), ARIES (ARtificial Intelligence for Ecosystem Services) (Villa et al., 2009), and Bayesian Belief Networks (Haines-Young, 2011). ARIES utilizes the Bayesian probabilistic network to determine the correlation among input and ES values contingent on data from other related sites that use the probabilistic benefit-transfer method.

3- ***Causal relationships*** are another method that is most commonly used to map ES (Martínez-Harms and Balvanera, 2012), whereby the land cover factors are linked to other biophysical factors based on the existing knowledge of the causal relationship to generate a proxy for ES (Eigenbrod et al., 2010; Martínez-Harms and Balvanera, 2012). Some of the examples involve recreation (Chan et al., 2006) and the prevention of erosion (Egoh et al., 2008) at the landscape-level and regulation of air quality and tourism at the global scale (Schulp, 2012). Causal relationships can be based on both primary and secondary data. Causal relations enhance the estimation of ES when primary data are missing and are easily applied to other areas or environmental conditions. Causal relations are

therefore a significant improvement over land cover-based proxies (Eigenbrod et al., 2010; Martínez-Harms and Balvanera, 2012). Nevertheless, creating a causal relationship requires a sufficient understanding of how ES are produced. The basic knowledge of how biophysical and social factors determine the delivery of ES remains low. Discrepancies arise and incorrect results can be drawn if the causal factors are weak predictors of ES (Eigenbrod et al., 2010; Martínez-Harms and Balvanera, 2012).

4- A ***biophysical model*** is a mathematical model that describes specific processes of ES or the biophysical environment, using quantifiable biophysical operations of the relationships among human and environmental factors that influence changes in the environment and ES. Biophysical models are often very complex, and they're based either on primary or secondary data. If there is an outstanding knowledge of this simulation model, causal relations may be collated and generalized into quantifiable biophysical models. Nevertheless, it remains a challenge to determine the right modeling complexity and consistent conformance of biophysical processes and responses (Rounsevell et al., 2012; Seppelt et al., 2012). For example, Seppelt et al. (2012) have shown that using look-up tables for mapping is preferable to complex models. Biophysical models offer a good estimate of ES if appropriate input-data are available and the models are properly calibrated (Nelson and Daily, 2010). Water supply (e.g., Naidoo et al., 2008) and Alcamo et al. (2005)) and carbon sequestration (e.g., Naidoo et al., 2008) are often obtained from biophysical models that use land cover and climate info (IEEP et al., 2009). Indeed, biophysical models could be even more data-intensive than the statistical models (Nelson and Daily,

2010; Vigerstol and Aukema, 2011). Biophysical models that are used to predict ES are versatile (e.g., GUMBO/ Multi-scale Integrated Models of Ecosystem Services (MIMES), Guo et al., 2000; Portela and Rademacher, 2001; Boumans et al., 2002; Boumans and Costanza, 2007), and they're often also spatially specific (e.g. IMAGE, PBL, 2006).

InVEST is currently among the most widely used and thorough ecosystem service mapping and modeling tools (Integrated Tool to Value Ecosystem Services) (Kareiva et al., 2011). InVEST, is an open-access GIS tool. It includes distinct models for several ES to analyze spatial patterns or monitor changes that are caused by land cover change by utilizing land cover data and other environment-related data (Crossman et al., 2013b). The intricacy of such models differs from proxy mapping to simplified biophysical production computations. InVEST has been used for mapping and valuing ES under diverse land cover situations such as those in Tanzania (Swetnam et al., 2011), and Oregon in the United States (Nelson et al., 2009). Bai et al (2008) utilized InVEST to analyze spatial interrelationship among biodiversity and ES in China. Guerry et al (2012) utilized InVEST in a Canadian case study to measure marine ES (Crossman et al., 2013b).

6- Formulation and Preference of Mapping and Modeling Methods

Several books, studies, and reviews focus on measuring, mapping, and modeling ES. Such studies differ enormously in the types of services studied, the scale of evaluation, and the method utilized to model and map ES (Seppelt et al., 2011; Crossman et al., 2013b; Villamagna et al., 2013). As a result, there's no general agreement on what's actually mapped and which method to use to model and map ES. It

may therefore be tough to distinguish studies, even though they interpret similar ES. There's no standardized, widely accepted way of mapping or modeling ES (Martínez-Harms and Balvanera, 2012; Crossman et al., 2013b). That's also true for the study of the impact of land management on these ES. Recent mapping and modeling studies on numerous ES refer mainly to land use and land cover only (Bennett et al., 2009). This knowledge-gap is a significant shortcoming, as the provision of ES within the land use type differs between different land management practices. All modeling and mapping approaches have their function, strengths, and weaknesses. Selecting the most appropriate method depends on the aim of the research and on expertise, data, and time constraints. Simple models require less data and expertise and are much easier to run. However, they often deliver less reliable results compared to complex models (Vigerstol and Aukema, 2011). The biggest challenge for mapping and modeling ES is to develop methods that are inherently advanced to portray the system but are also simple enough to be still comprehended and parameterized even with limited data (Tallis and Polasky, 2011). For example, Crossman et al. (2013a) call for even a stronger link between biophysical models and high-resolution data and the production capacity of ES. At least, biophysical models, proxy-based methods, probabilistic relationship transfer, and causal relationships are partially based on secondary data. This makes these approaches suitable when primary data is limited. All of the four approaches, except the statistical model, involve causality, making them useful to understanding and extrapolating the impact of land management on ES. This paper will therefore use biophysical models compatible with the InVEST method to model and map ES.

E- How does Ecosystem Services Mapping Improve the Management of Biosphere Reserves

Maes et al. (2012) offer a comprehensive view of the rationale for mapping ES. The authors note that the analysis of the spatial distribution of various ES at different spatial scales is an essential area of application for data based on modeling and mapping exercises. The rationale for mapping ES varies greatly from one study to another, including evaluating the spatial congruity of ES with biodiversity, assessing trade-offs and synergies between distinct ES, evaluating trends in ES, measuring costs and benefits, trying to compare the supply of ES with demand, attempting to find the economic estimate of biophysical quantities, or prioritizing regions in spatial management and planning. In certain cases, there's a direct relationship between the research's goals and the spatial scale at which these mapping and modeling exercises are conducted.

Both the evaluation of the spatial configuration of services and their measurement are basic prerequisites for all mapping exercises. For instance, Burkhard et al. (2009) focus mainly on quantifying the ES on their own or quantifying the potential of ecosystems to provide services. They present a general approach (i.e., a matrix) for assessing the capacity of various landscapes that offer ES. The authors also discuss how they used this methodology in several case studies, one of which was in Schwäbische Alp, S-Germany for establishing the Biosphere Reserve and because ecosystem services rely on the quality, existence, and distribution of natural environments, their investigation necessitates the collection of spatial data covering the entire biosphere reserve. Hence, mapping strategies allow for the visualization of the distribution of ecosystem services in biosphere reserves, and their analysis will aid comprehension of the findings.

Now that we've seen how important mapping ES is for better managing a biosphere reserve, it's critical that the literature also examines the different ways for sustainable agriculture in Biosphere Reserves in relation to natural ecosystem conservation, which will be discussed in the following paragraph. This will help in determining the best way to manage the agricultural lands of this paper's case study.

F- Different Case Studies related to Sustainable Agriculture in Biosphere Reserves Adopted by Managers in Relation to Natural Ecosystem Conservation

Proper land management and sustainable agriculture in biosphere reserves are urgently needed because they allow for the preservation of natural resources, as well as economic growth and prosperity, ecological integrity, and public health. Some of the farmers' best management practices include encouraging water conservation through drip irrigation and disseminating good practices such as conservation agriculture, organic farming, and integrated pest management, to name a few.

The following three case studies demonstrate how managers used sustainable agriculture to conserve biosphere reserves (UNESCO, 2008):

1- China's Chebaling Biosphere Reserve:

The biosphere reserve, which is located in Guangdong Province, is home to ethnic groups like the Yao. The reserve's managers and the locals are at odds over resource extraction in this biosphere reserve. The solution was to promote and enhance agricultural production and techniques, which would improve local livelihoods and bring harmony.

2- Germany's Elbe Biosphere Reserve Riverlandscape:

The biosphere reserve, located in the middle stretches of the Elbe River, is home to 270,000 people, with intensive agriculture accounting for 70% of the land area, resulting in land degradation. Managers developed sustainable agricultural systems to restore the landscape, such as new pasture landscape formation for livestock grazing, water-level management, and traditional- grassland-use.

3- Colombia's Seaflower Biosphere Reserve:

The biosphere reserve, which is situated in the west Caribbean, includes the Old Providence, Archipelago of San Andres, and Santa Catalina, Colombia. 78,000 people live in the biosphere reserve, which includes native islanders of minorities such as "Raizales." The locals engage in poor agriculture practices. The locals engage in poor agriculture practices. Managers of the biosphere reserve work hard to integrate productive traditional agricultural techniques with low-tech alternative solutions to boost socio-economic, and preservation benefits, such as specialized programs to safeguard native islanders' natural and cultural environment.

Finally, while exploring the literature, it was discovered that E.S mapping is not widely used to assess biosphere reserve management; thus, the goal of this paper is to create maps of the food supply in Jabal Moussa Biosphere Reserve to raise local awareness about areas of ecosystem goods production and consumption, allowing for better management and long-term sustainability.

CHAPTER III
CASE STUDY PROFILE: JABAL MOUSSA BIOSPHERE RESERVE

Jabal Moussa Biosphere Reserve (JMBR) and its surrounding villages were inducted into the UNESCO MAB Program in 2009. By combining natural sciences with economics, social sciences, and education, JMBR aims to improve human well-being and nature conservation. This biosphere reserve is indeed a fascinating location that incorporates a rich environmental and cultural heritage with phenomenal biodiversity and local species. Its long track record, especially rural activities and socioeconomic trends, provides an original context for action that is very relevant for this study, which aims to map food provision ES to improve land management decisions, and to do so, it is critical to understand first Jaba Moussa's profile as a whole in all of its parts in this chapter, as briefly summarized in ***Table 3***.

Table 3: Jabal Moussa Biosphere Reserve Features

Jabal Moussa Biosphere Reserve Features	
Year of designation	2009
Ecosystem/landscape	Mountain Forest
Terrestrial and marine surface area (ha)	6500
Population	15000
The main economic activities of the local inhabitants	Small-scale and large-scale agriculture (ex: crop production, fruit trees, and beekeeping)
	Ecotourism
Organization in charge of management	The APJM
Focus of biosphere reserve activities	Mountain preservation and restoration
	Sensitization of the community to conservation and sustainable development
	Research, particularly on biodiversity and geology
	Environmental education for youth in schools
	Small-scale and large-scale agriculture
Linking sustainable development and conservation (examples of measures)	Fostering collaboration between conservation and development organizations, as well as the private sector
	Increasing community awareness of conservation and development through demonstration projects
	Holding capacity-building workshops for local inhabitants
	Stakeholder projects for sustainable resource use
Link to superior political levels	Ministry of Agriculture
	Ministry of Environment

A- Location & Population

Jabal Moussa Biosphere Reserve (JMBR) is situated in the district of Kesrouan, Lebanon, 45 km away from Beirut city, as shown in Figure 5. It includes seven villages, which are: Qehmez, Yahchouch, Ghbeleh, Jouret el Thermos, Chouwan, Ebreh, and Nahr Ed-Dahab. They are distributed over altitudes from 350 m - 1,700m (Karam, 2016). Jabal Moussa covers an area of 6500 ha, comprising 1,250 ha of protected zone, 1,700 ha of buffer zone, and 3,550 ha of development zone (Karam, 2016). It has a population of 15,000 people (Karam, 2016). Permanent inhabitants are elderly villagers who make up only 20% of the people living there (Sa et. al, 2017). Because the majority of residents (aged 40 and up) do not have a high level of education, they farm and are skilled at it; they also graze animals, primarily goats and sheep, because moving cows up the mountains is difficult. Those under 40, on the other hand, are well educated, with either a high school diploma or a university degree, and work in Beirut due to a lack of job opportunities in Jabal Moussa. It is worth noting that Jabal Moussa has a large number of churches that serve to strengthen people's religious beliefs as they visit on a regular basis, but it does not have a large number of schools.

Figure 5: JMBR's geographical location on the Mount Lebanon Range (Source: https://www.freeworldmaps.net/asia/lebanon/map.html)

Figure 6: The Northern side of Jabal Moussa Biosphere Reserve

B- Ecological and Cultural Characteristics

Jabal Moussa that overlooks the Mediterranean Sea to the west, is a real mosaic of ecological systems widely representative of the "evergreen sclerophylic broussailles and forests" biogeographical zone within the Mediterranean biome, as shown in ***Figure 6***. (Jabal moussa: United Nations Educational, scientific and Cultural Organization, n.d.)

A dominant characteristic of this biosphere reserve is its untouched landscape of steep, green hillsides rising from a river lined with fresh, aromatic sycamore trees to the summits of statue-like karstic rocks. (Jabal moussa: United Nations Educational, scientific and Cultural Organization, n.d.) Jabal Moussa is exceptional because it hasn't yet been impacted by unchecked urbanism, the expansion of roads and quarries that have destroyed other similar mountains. (Jabal moussa: United Nations Educational, scientific and Cultural Organization, n.d.)

The numerous valleys of Jabal Moussa generally run in the direction of the EN-WS. The mountains give rise to a range of eco-zones, thereby fostering the diversity of many species. (Jabal moussa: United Nations Educational, scientific and Cultural Organization, n.d.) There are at least 728 species of plants (e.g., Kermes Oak, Calabrian pine, Hop-hornbeam, Syrian juniper, Manna ash, Storax, Three-lobed Apple, Tauras Maple, Cyclamen, Peony, Orchid, and Lebanon marjoram) 25 species of mammals (e.g., Hyena, Wolf, Porcupine, Wild Boar, Squirrel, Hyrax, as shown in ***Figure 9***, and more than 137 species of soaring and migratory birds. (A Walk Through Jabal Moussa, n.d.) In the core area alone, it has been possible to classify 14 phytoecological classes

and two agricultural types. (Jabal moussa: United Nations Educational, scientific and Cultural Organization, n.d.)

Several experts, such as George and Henriette Tohme, two university professors specialized in this field, have studied the different types of plant species in Jabal Moussa thoroughly for many years and published a book on them called “Illustrated Flora of Lebanon”. The number of animals is still unknown to this day. Their number could have been decreased or increased. The most visible animal in Jabal Moussa is the hyrax, while the least visible ones are the hyena, wolf, and wild boar that have been discovered through cameras placed in areas that are inaccessible to humans. The guards scatter food around the reserve, so these animals will come out for the cameras to spot them. Their habitats could be the location they're spotted in. It is also prohibited for any person to practice hunting in the biosphere reserve. Unfortunately, some people do not abide by this rule and hunt around the reserve even though there are several "No Hunting" signs. There are also a lot of beekeepers outside the core area because cars can't get inside.

From a more aesthetic perspective, the different landscapes, dominated by peaks and basins, offer beautiful, infinite views that are influenced not only by the geographical position but also by the range of altitudes and the exposure of slopes in numerous directions. (Jabal moussa: United Nations Educational, scientific and Cultural Organization, n.d.) Similarly rich in cultural heritage, it illustrates the interconnectedness of Man and Nature across history through numerous historical and spiritual sites dating back to the Phoenician, Roman, and Ottoman times (e.g., the Cross-Site, the Roman Stairs, shown in ***Figure 10***, the Stele depicting Phoenician god Adonis, the Hadrian Inscription, El Byut, the Roman Tomb, the Roman Basin, the

Ottoman watermill, the Ottoman bridge, the Limestone Kiln, and Jannet Chouwen Lake, depicted in ***Figure 8***, which flows into the Adonis River., as well as many others). (A Walk Through Jabal Moussa, n.d.)

Figure 7: Jabal Moussa's dense forests (Source: A Walk Through Jabal Moussa, n.d.)

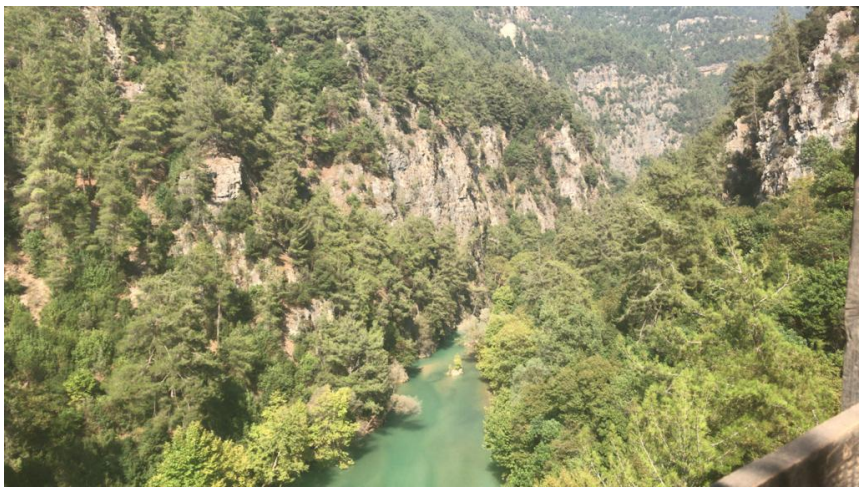

Figure 8: Jannet Chouwan Lake

Figure 9: Rock hyrax (Source: A Walk Through Jabal Moussa, n.d.)

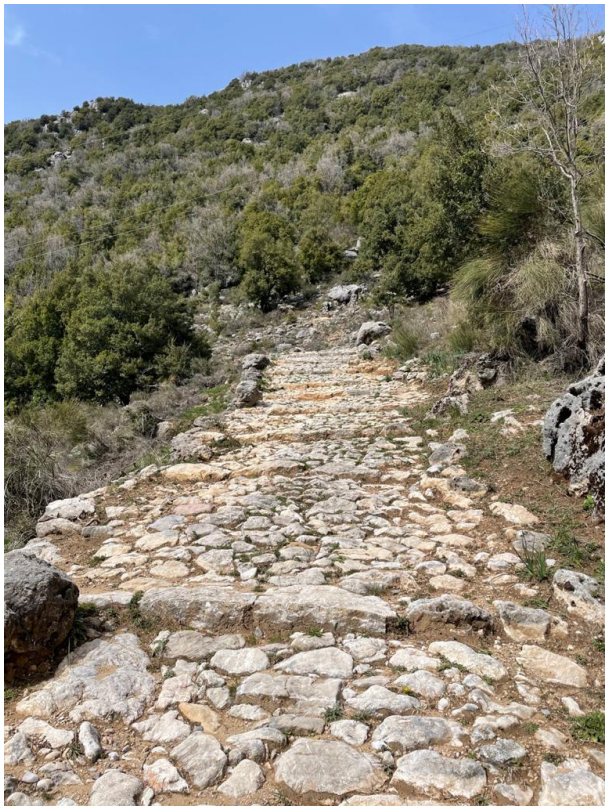

Figure 10: Roman Stairs

C- Human Activities

The transition zone occupies approximately 54.5 percent of Jabal Moussa, with charcoal production, quarrying, conventional agricultural practices, fruit trees planting, grazing, forest management, and seasonal recreation being the dominant land use. (Jabal moussa: United Nations Educational, scientific and Cultural Organization, n.d.) Within the low population (15,000 individuals) of Jabal Moussa, local communities acquire direct income from selling home-made products (ex: thyme, jam, honey, and handicrafts), renting rooms or houses for overnight stays, cooking to provide local healthy food to workshop participants in villages, guiding tourists to visit the reserve including natural and historical monuments, and selling items sought by tourists, as shown in ***Figure 11***. (Jabal moussa: United Nations Educational, scientific and Cultural Organization, n.d.) Nevertheless, there are some bad practices by locals in Jabal Moussa, such as hunting, camping, lighting fires, grazing, cutting down wood, and resource encroachment, that occur in different zones of the biosphere and will be discussed in detail in sections E and G of this chapter. This chapter will also discuss JMBR management, but first, we will look at the biosphere reserve's zonation scheme in the following paragraph.

Figure 11: Products from Jabal Moussa's gift shop (Source: A Walk Through Jabal Moussa, n.d.)

Figure 12: Jabal Moussa Workshop/ Kitchen

D- Jabal Moussa Biosphere Reserve's Zoning Scheme

The Association for the Protection of Jabal Moussa (APJM), a Lebanese non-governmental and non-profit organization founded in 2007, manages Jabal Moussa Biosphere Reserve. However, it was not until later in 2009 that UNESCO decided to name Jabal Moussa and its neighboring villages (Qehmez, Yahchouch, Ghbeleh, Jouret

el Thermos, Chouwan, Ebreh, and Nahr Ed-Dahab) as a biosphere reserve under the MAB Program because it met the criteria. The JMBR zonation scheme was established by the APJM, who divided the area into three concentric zones (core, buffer, and transition zones), as shown in ***Figure 13***, and will be discussed in detail below.

1- Protected Zone (core area): this area includes steep slopes used to avoid soil erosion, glades, water bodies and dense forests, as shown in ***Figure 7***; it also contains dense and clear oaks, scrublands, clear pines, rocky outcrops, and bare rocks, as shown in ***Figure 20***. Only the small villages with a very minimal number of people living there, such as Chouwan and Ebreh, are completely within this region (A Walk Through Jabal Moussa, n.d.). Other bigger villages are partially in the buffer area, and the rest are in the transition area.
2- Buffer Zone: People have limited access to this zone, which includes all areas outside the existing hiking trails. This area contains surface water, a bit of dense and clear oaks, dense and clear pines, and few scrublands, as shown in ***Figure 20***. The villages present in this zone are Yahchouch, Qahmez, and Nahr Ed-Dahab (A Walk Through Jabal Moussa, n.d.).
3- Transition Zone: People have free access to this zone, which includes also some hiking trails. This area contains surface water, a bit of dense and clear oaks, scrublands, clear pines, seasonal crops in small terraces (e.g., Green Beans, Red Beans..etc.), fruit trees (ex: Tomato, Cucumber, Peach, Plum, Pear, Apple,..etc), and mineral extraction sites, as shown in ***Figures 19 and 20***. The villages present in this zone are Jouret el Thermos, and Ghbeleh (A Walk Through Jabal Moussa, n.d.). Most of the human activities are done in this area.

Land ownership in these areas varies immensely, with the majority being endowment and private lands. The biggest landholder is the Lebanese Maronite Patriarchate. The Association for the Protection of Jabal Moussa (APJM) signed a medium-term rental contract with the landholder for sustainable ecotourism and environmental preservation (A Walk Through Jabal Moussa, n.d.). The municipalities of Yahchuch and Ebre are also major shareholders in these regions. In the following sections, we will look at how locals treat these zones and how the APJM manages them.

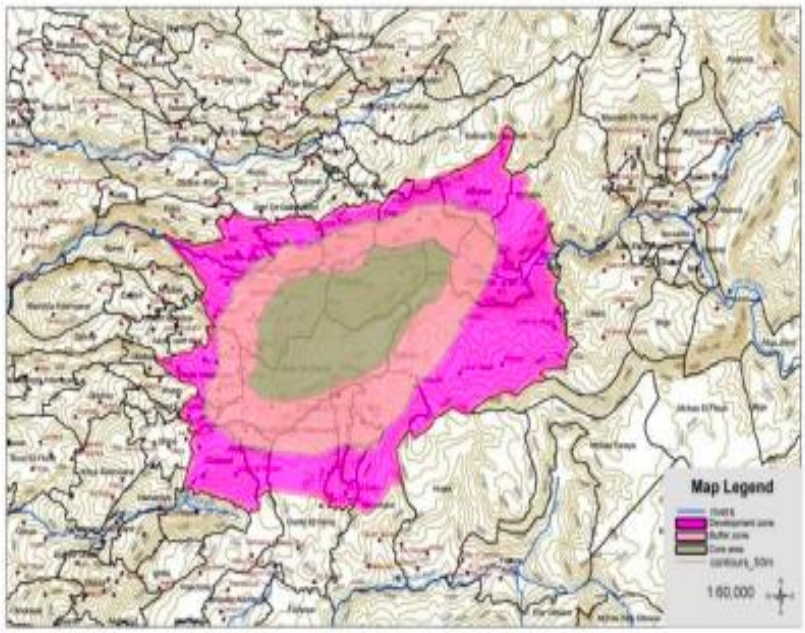

Figure 13: Jabal Moussa Zonation Map (A Walk Through Jabal Moussa, n.d.)

E- Jabal Moussa Biosphere Reserve's Management

1- Biosphere Reserve Management: The Association for the Protection of Jabal Moussa (APJM)

The APJM team manages Jabal Moussa Biosphere Reserve through an executive committee (President, Vice President, and Accountant, Board Members, Secretary, Treasurer,Communication & Agroproduction Coordinator, Ecotourism Manager,Executive Director, Field Operations Coordinator, Financial Manager, Rural Development Coordinator, and Guards).The MAB Program, of which JMBR is a part, inspired the APJM to abandon the traditional conservation approach, which excluded people from the core area (i.e. protected area), in favor of a human-centered approach that included local communities. The endangered and threatened mountain of Jabal Moussa has evolved into a flourishing ecotourism-destination, progressively making contributions to the wellbeing of its local communities, following the help and support of several donors, such as Mr. Khalil Fattal, the Embassy of Italy in Beirut, the Mediterranean Eco-Tourism Experience, the Embassy of the USA in Beirut, Banque Libano-Française, Drosos, and USAID to name a few. The chiefs (mukhtars) and mayors (ra'ees baladiyeh) of the villages, on the other hand, did not contribute any funds, nor did Lebanon's Ministries. The APJM's activities (i.e. tourism, public awareness campaigns, economic activities, and so on) span several areas of the biosphere reserve, which will be thoroughly discussed below.

a- <u>Benefits to the Communities</u>

During an interview with a guard at JMBR it was mentioned that the APJM ensures that residents of Jabal Moussa's surrounding villages benefit from the

reserve, contributing to the villages' economic growth. Many villagers are benefiting, and proof of this is that many residents are working with the association. The APJM owns a large kitchen in Jourt el Termos, as shown in ***Figure 12***,which contains a lot of equipment and machines that help with food production. The APJM only purchases food crops and raw materials from the surrounding villages, and skilled women from those villages prepare food (e.g., vinegar, thyme, honey, jam, sugar, pine nuts, tomato paste etc.) in the kitchen, which are then sold in Jabal Moussa's gift shop and several stores throughout Lebanon under the brand name "Jabal Moussa". Majority of the buyers usually purchase thyme and honey. However, if the APJM wants to sell a product, such as tomato paste or fig rolls, and the farmers in the surrounding villages are unable to grow the seasonal fruits required to make the products, the APJM will purchase them from other villages in the Kesrouan area. The APJM also buys handicraft products from disabled people, who work from home, to sell them in their gift shops knowing that it makes minimal profits just so that these people can benefit from the reserve. Furthermore, the APJM only hires locals to work with them either as reforestation and forest managers, nursery managers, tour guides, guards, cleaners, etc. They also purchase a variety of products from local markets, such as stationary, detergents, kitchen equipment, and so on.

b- Eco-tourism

In addition, the APJM started with three hiking trails in Jabal Moussa, and today there are fifteen trails, as shown in ***Figure 17***. There are people like Mr. Khalil Fattal, one of Jabal Moussa's leading investors, and Mr. Sami Beydoun, who helped

APJM expand beyond the three known paths. There are, however, a number of places within Jabal Moussa that are not accessible to people due to rocky paths. To become a hiking trail, a location must have historic or cultural significance, or it must contribute to pleasant walks with beautiful scenery. If the APJM deems this area fit, it sends people to fix the trails and put up signposts so tourists don't get lost while hiking with the funds it receives. Finally, the APJM adds the new trails to their brochure. The trails have generated a local ecotourism with lodging facilities and snack areas. It is worth noting that the APJM also created a path specifically for grazing called the "shepherds encounter," to allow the shepherds to graze during the spring and summertime, but the shepherds do not walk along these paths and instead allow their flocks to graze everywhere in Jabal Moussa, destroying the reserve.

c- Land Degradation

During an interview with two of APJM's team members, it was mentioned that there used to be a lot of stripping, drilling, and crushing equipment out there in Jabal Moussa, as shown in ***Figure 14***. Workers started using these machines long before Jabal Moussa became a reserve. Furthermore, many quarries have been opened in and around Jabal Moussa for material extraction, either by stripping the surface or by blowing them up with explosives, and then using crushers to turn the large stones that have been extracted into smaller ones. These machines have damaged several mountains, reduced the amount of water resources to a point of scarcity, and caused soil erosion. The soil fell on the streets and on some of the houses; it was also difficult for people to reach their homes and lands during the winter, due to massive specks of dust. The APJM requested that the ministries issue

tickets for violations of illegal investment in crushers, but the owners of the crushers would simply pay the fine and continue to use the machines. The APJM also requested assistance from municipalities, but nothing could stop these people from excavating because people with significant political clout backed them up. It wasn't until a year and a half ago that the President of Lebanon issued an order prohibiting the use of these crushers in Jabal Moussa, particularly in the core area and in areas where they pose a threat to the environment. Only a few machines continue to operate in quarries in Wata El Joz to extract rocks because they have legal permits issued by the Ministry of Environment to do so. The APJM is also attempting to restore damaged areas in Jabal Moussa, such as a deserted limestone quarry and a damaged section of the Roman Stairs.

Figure 14: The Mchati entrance to Jabal Moussa Biosphere Reserve, which was disrupted by quarrying in 2011 (Source: https://www.jabalmoussa.org/sponsor-popup.php?id=32255)

d- Waste Management

Before, the core area had been subjected to extreme agriculture, hunting, camping and lighting fires, grazing, land-use (for example, when inhabitants pollarded forests for their thick wood for charcoal and firewood production), and

waste dumping, all of which the APJM was able to prevent. There was also a policy number 1/399 "Establish a Protected Forest in Jabal Moussa" issued by the Ministry of Agriculture on September 18, 2008, which prohibits such actions in the core area. The APJM provides composting bins at the entrance. They also recycle trash and deliver it to a recycling facility in Kfour. The APJM also recovers and valorizes organic waste through composting in their kitchen in Jouret El Termos, with the assistance of a Lebanese social enterprise called "Compost Baladi." However, we can still see intense human activity in the buffer and transition area because these are private lands owned by a variety of people, and there is a conflict of interest between them and the APJM team. The APJM prevents people from harming the environment in the core area, which includes the rocky areas found in this region, but they have no control over what happens outside of that area.

e- Community Awareness

Previously, not all villagers were aware of the features of Jabal Moussa, and as a result, they were unaware of its economic, social, and environmental significance. All villagers saw was aesthetic beauty, which they took for granted. As a result, they were unconcerned about environmental preservation, hence the APJM launched awareness campaigns to make the residents of the surrounding villages aware of the socio-economic and environmental value of the biosphere and to expose them to the products and services provided by the reserve. The APJM frequently tries to convince villagers' to cooperate with the association. The inhabitants surrounding Jabal Moussa began to realize the true monetary and non-monetary value of the reserve, seeing how the reserve attracts a number of tourists. The villagers and tourists stopped littering in front of the main entrance to the

reserve. The APJM also promotes development by holding training sessions for specific types of farming including beekeeping, with funding from USAID. They bring in professionals to teach farmers proper and effective bee-keeping techniques. The APJM is currently planning workshops on food safety. In addition, there is a book called "Tabsoun Tabsoun" with a series of children's adventure novels, published by Najib Kassar, with the rock hyrax (i.e. Tabsoun) being the central protagonist. The aim of the series is to raise children's awareness about the importance of the environment and to present them to the plants and animals in Jabal Moussa through a thrilling and amusing adventure with Tabsoun. Through this friendly and fun character, children are becoming more interested in the discovery of nature. Tabsoun is now known as the mascot of the APJM. A large colorful Tabsoun costume is present at most of Jabal Moussa's events, and it accompanies the APJM team when they visit children in their schools. Furthermore, the APJM promotes JMBR on websites, Instagram, television commercials, and other platforms in order to attract both domestic and international tourists. The APJM also promoted villages and regions that were previously unknown to the public. Folks now visit these villages to eat at their restaurants, shop at their small shops, and stay the night at a Bed and Breakfast or Guesthouse.

f- Plant and Tree Propagation

The APJM also maintains 3 native tree nurseries in 3 villages around Jabal Moussa, which holds thousands of seedlings every year. The trees that grow in the nurseries come from the seeds collected from Jabal Moussa's own trees, and they are well cared for by local villagers. Some of the seedlings are planted at deteriorated sites in Jabal Moussa when they are ready for out-planting. The

seedlings also contribute to national reforestation initiatives. Thousands of seedlings from Jabal Moussa have been replanted across several different sites in Lebanon. The APJM also grows wild native trees (e.g., wild pear and wild plum), pine trees, cypress, and carob in the nurseries to sell to people.

g- Wild Fire Management

During an interview with the APJM, they mentioned how a fire broke out last year in the Chouwan area as a result of waste burning and unconfined waste disposal along the road, as well as burning wastes near to extremely flammable fuel, prompting the APJM to set up water supplies to assist firefighters during future fire outbreaks. In addition, the APJM also put some water outputs and hoses along the hiking trails. Nevertheless, the existence of multiple waste disposal sites increases the risk of fires spreading to nearby agricultural lands. As a result, it's critical to close all current waste disposal sites and prohibit waste burning in these regions in order to reduce the risk of fire. There is also the risk of fire outbreaks in camping and picnic areas like Chouwen.

As mentioned above, we can see how the APJM is open to understand traditional knowledge and focuses in specific on traditional women's knowledge. It also uses scientific research to improve management efficiency. However, there are still some things that can be done better. Several management areas, particularly the management of agricultural practices occurring in all biosphere reserve zones, require improvement. Farmers rely heavily on the environment's resources, but agrarian

structural changes significantly impact their work, prompting them to oppose the concept of protected area management and refuse to stop such activities.

F- The Economic Advantages of Jabal Moussa Biosphere Reserve for Local Communities

1- Ecotourism

As shown in ***Table 5***, JMBR provides a wide range of both tangible (i.e. wood, fruits, vegetables, etc.) and intangible (clean air, cultural heritage, aesthetics, etc.) ecosystem services that provide economic benefits to the community. It not only provides direct commercial payoffs from these services, but also indirect benefits (which aren't immediately apparent to people), that have value. For example, JMBR contributes to economic growth to the area through ecotourism. According to a guard working in JMBR in 2007, only 300 people visited the reserve and the majority were foreigners. Today there are about 300-500 people a day, many of whom are nationals. Last year, they had over 30,000 visitors because the core area is well managed in terms of cleanliness and aesthetic. The biosphere is also well marketed, allowing both locals and visitors to learn about it. There are also several trails to hike and sights to see, not to mention the opportunity to get away from the city.

The entrance fee is 8000 L.L. for adults and 4000 L.L. for children as shown in ***Table 4***. Moreover, highly trained guides of all ages and genders accompany tourists along the hiking trails. Following that, the hiker has the option of eating at a local restaurant/ snack shop or spending the night in a guesthouse or a Bed and Breakfast (B&B), with

prices ranging from 90,000 LBP/night and up. There are also very few inhabitants who own wineries, such as the St. Andre winery in Ghbeleh, which hosts weddings.

Table 4: Total numbers of visitors to Jabal Moussa Biosphere Reserve and total Gross Revenue from 2018-2020 (Source : Association for the Protection of Jabal Moussa (APJM)

Year	**2018**	**2019**	**2020**
Visitors above 16 years old	23706	23616	34180
Visitors under 16 years old	4941	6095	5911
Total Number of Visitors	28647	29711	40091
Entrance Fees above 16 years old	8000 LBP	8000 LBP	8000 LBP
Entrance Fees below 16 years old	4000 LBP	4000 LBP	4000 LBP
Total Gross Revenue from Entrance Fees	**209 412 000 LBP**	**213 308 000 LBP**	**297 084 000 LBP**

2- Agro-Products and Sales

The people of Jabal Moussa follow a traditional rural way of life centered on agriculture, which provides numerous economic benefits. During an interview with the locals, it was mentioned that local women process honey, fruits, and herbs in a kitchen in Jouret El Termos, which is supplied by beekeepers and farmers. Women artisans that use simple and basic techniques and frequently recycled materials create handicrafts. Moreover, people with disabilities make some of the handicrafts. Visitors and hikers can purchase these handicraft and agro-food products from guards at some of the reserve's entrance gift shops. The prices of the products range from 4,500 to 200,000 LBP. The most popular products sold are honey (100,000LBP) and thyme (5,000 LBP/

unit). Residents of Jabal Moussa are also storing food (i.e. mouneh) picked from their agricultural lands on their home shelves for the winter, as shown in ***Figures 15 and 16***.

Figure 15: Residents of Jabal Moussa storing food (i.e. mouneh) on shelves for the winter

Figure 16: Agriculture land owned by Jabal Moussa residents

Figure 17: Hiking Trails in Jabal Moussa (Jabal Moussa, n.d.)

During interviews with local farmers, they mentioned how they preserve native plant nurseries, which have become a point of interest for foreign and local visitors who may want to plant a tree and help restore disrupted mountain areas. Native trees cost between 12,000 and 25000 LBP per unit. Farmers manage their own private lands and grow a variety of seasonal crops such as strawberries, grapes, apples, peach, plum, cucumber, and tomato, to name a few as shown in ***Table 5***. There are many fruits that they do not grow, such as lemons, avocados, sugar apples, and so on. The farmers use these agriculture products for subsistence and for selling purposes. They sell their products to domestic and foreign markets in the Middle East, such as Jordan, Iran, and Egypt. Their crop products were sold locally at prices ranging from 1000 LBP/kg and up, and internationally at slightly higher prices to compensate for transportation costs. Of course, with the current economic crisis, crop products are being sold at higher prices due to the decrease in LBP value. Furthermore, data on the amount of wood

extracted by residents and the stumpage-price (prior to transport) were obtained from a socioeconomic survey conducted in 2009. The 2014 value was calculated using discount rates. The price of wood for the total surface-area of Jabal Moussa's forests as well as other woodlands were calculated to be around 20.84$ / ha (Karam, 2016).

Many locals' lives have changed as a result of the biosphere reserve because they have found work or a part-time job that generates income from all of the previously mentioned activities. They're not only empowered economically but also socially because they're deeply committed to the preservation quest and never skip an opportunity to express their joy in having ties to JMBR as a whole (i.e. its mountains and people).

G- Negative Impacts on the Reserve

Human impacts on the lands surrounding JMBR (i.e. mining, quarrying, building construction and similar infrastructure such as roads, sewer systems, and dams, throwing garbage in waste dumps, hunting, grazing, cutting down trees for charcoal production, excessively and improperly cutting plants such as thyme, etc.) have had a negative impact on the reserve. The APJM has found it difficult to put a stop to these incidents in the buffer and transition zones because they occur on private lands owned by those people and with municipal permission. The APJM can only stop locals from engaging in these activities in the core area because they leased the land from the Maronite Church and thus have full authority to do so. They are even having difficulty preventing people from hunting birds, especially in the core area, which is a problem given the reserve's abundance of rare bird species.

Furthermore, the APJM cleans up in front of the entrances and hiking areas; however, they cannot prevent people from littering in the buffer and transition zones.

People in the villages throw garbage on the streets and in their parking lots, causing it to pile up and fall into the mountains below, where it cannot be reached or removed. You can also see a used car left on the side of the road that appears to have been there for a long time with good parts removed from it. People are unaware of the significance of environmental preservation; they are also unconscious of what they are doing. People no longer make an effort to recycle, compost, or avoid littering because it has become a human norm. This is rapidly becoming a major local issue. There must be a way to force them to change their habits and norms.

There are also numerous waste sites, which contribute to fire outbreaks. Furthermore, there are no private sectors in Jabal Moussa to clean up, such as Sukleen, and municipalities do nothing to prevent people from throwing waste at random. They wish to maintain power by winning elections. They would rather make people happy than keep them safe.

To put a stop to such activities in the JMBR, stricter regulations must be implemented. High fines, for example, should be imposed on those who hunt bird species, graze beyond grazing trails, litter, cut down trees, and so on. Moreover, people could be incentivized if they use garbage cans. Also, colored footprints can be positioned on the ground to direct people to the closest garbage bin; this is a low-cost, simple, and efficient behavioral design.

Moreover, some farmers engage in agriculture, particularly in the core area, as this is where they live, to benefit from agricultural produce. According to interviews with farmers, they started to feel dismantled because they're no longer entitled to determine how to cultivate their lands, especially the ones living close to the core area. Far too many laws govern agriculture, in their opinion. They were aware of the reserve

and its prospects, but they had no idea how it could offer benefits to their farm, or agriculture overall. They're most likely to oppose the APJM's conservation management practices, and it may take considerable effort on the part of the APJM to gain their support. This is why mapping food provision ES is critical for better managing the biosphere reserve for long-term sustainability, which is what this paper aims to do.

H- Impact of Covid and Economic Crisis on the Locals' Livelihoods

On August 4, 2021, a devastating explosion struck Beirut, wiping out half of the city. The blast occurred at a difficult time for Lebanon, which is dealing with not only the spread of the coronavirus but also a severe economic crisis, with local currency devaluation. The blast and the pandemic sparked an even greater economic collapse, resulting in the worst recession in modern Lebanese history, delivering a huge setback for those at or near the top and an even greater depression-like blow for those at the bottom, making a lot of people poor. Furthermore, banks in Lebanon have imposed foreign exchange restrictions, limiting people's access to foreign currency at the bank rate, resulting in an increase in the price of everything sold in markets. The volatile economic situation in Lebanon is encouraging locals to invest more in their land through agriculture in order to maximize profit. Furthermore, the current economic situation is diverting inhabitants' attention away from purchasing fuel and toward tree cutting for winter heating.

Because of the coronavirus outbreak and economic crisis, many citizens of Jabal Moussa were laid off or lost their jobs in Beirut. It is now much cheaper for businesses to work online, and with the economic crisis, few businesses can compensate for their losses. The locals of Jabal Moussa, who lost their jobs returned to farming, but their

income is insufficient to support their families and pay for their children's education. Many even purchased cows, goats, and sheep in order to raise them and sell dairy products. These farmers must pay for a variety of expenses, including workers for land maintenance and crop production, pesticides, cow feed, livestock vaccination, and drip irrigation repair. Paying for all of this is very expensive, and selling their products locally at a very low price does not compensate for these costs. This is why shepherds allow their herds to graze at random in the biosphere (especially in the core area) during the spring and summer time; it is much cheaper for the shepherds if their animals eat from the biosphere rather than buying food; however, grazing is destroying the environment as a result.

Locals who have been permanently laid off as a result of COVID are now forced to return to farming, resulting in more irregular agricultural practices in the biosphere reserve. This emphasizes the importance of mapping the food provision ES in JMBR to determine whether these practices are prevalent in the core area, which is prohibited, and if so, to shed light on the matter and propose ways for the APJM to better manage the reserve.

I - Impacts of Climate Change on Jabal Moussa Biosphere Reserve

1- A brief overview of climate change impact and projections in Lebanon

Because of its desirable climate and localized conditions resulting from its diverse topography, Lebanon can deliver a wide variety of crops. Vegetables (particularly tomatoes and potatoes), cereals, citrus and other fruits, grapes, and olives are among the main crops. The Bekaa Valley (including West Bekaa and Zahle), Northern Lebanon (especially Koura and Akkar), and the Southern coastal areas

are the main harvested areas. Other agricultural regions are largely fragmented and usually don't exceed 1 ha in size, but they account for 20% of the total cultivated area (ACSAD et al., 2017). Temporary crops, permanent crops, and greenhouses cover 232,200 ha (23 percent of the country) (ACSAD et al., 2017). Permanent crops account for 54% of total cultivated land (ACSAD et al., 2017). Pulses, cereals, vegetables, industrial crops, and fodder crops, are temporary crops that account for 44% of cultivated land. Greenhouses house account for the remaining 2 % of crop areas (ACSAD et al., 2017).

Although agriculture accounts for only 6.3 percent of GDP, commodities account for 17 percent of export values (ACSAD et al., 2017). The sector employs the majority of the rural populace as a primary or secondary source of revenue (ACSAD et al., 2017). Numerous challenges are causing concern in the sector. The semi-arid climate and projected climate change, which indicates rising temperatures and decreasing precipitation, increases reliance/demand on water resources, especially for irrigation use (ACSAD et al., 2017). The effects of climate change on agriculture raise concerns about Lebanon's future growth and development, including food security. Furthermore, the agricultural market is frequently volatile, which can minimize rural earnings (ACSAD et al., 2017). Moreover, the government's responsibility for the latest research and technology is limited (ACSAD et al., 2017).

Fourteen percent of Lebanon's areas are expected to be highly vulnerable. Areas with the greatest vulnerability include Akkar, Rachaya, and Hasbaya Cazas, and a few small regions in the Beqaa Valley. Crops in these areas, such as apples, grapes, olives, and vegetables, will be negatively affected (ACSAD et al., 2017). Furthermore, 84 percent of croplands equidistant to these high vulnerable areas,

including Bcharre and Hermel Cazas, indicate moderate vulnerability; crops such as apples, almonds, and olives could be harmed in these areas; and the remaining regions in Lebanon, including the Jabal Moussa Biosphere Reserve, indicate low vulnerability (ACSAD et al., 2017).

2- Impact of climate change on agriculture in Jabal Moussa

According to farmers interviewed, as Lebanon's climate changes, so do its negative consequences on Jabal Moussa, such as decreased crop quality and quantity due to a shorter period of growth followed by high temperatures; an increase in weeds and harmful pests in crop plants; decreased land fertility due to exponential biodegradation of organic matter; and an increase in soil erosion as a result of heavy rains. Farmers living in Jabal Moussa, were unable to grow tomatoes as efficiently as in previous years in order to sell to consumers and make tomato paste due to climate changes; it was extremely humid, which resulted in several fungi tomato diseases, including powdery mildew. Farmers were also having problems with certain worms as a result of climate change, and they couldn't afford pesticides at such high prices, especially given the Lebanese Lira's depreciation. They couldn't get rid of the worms, and a lot of crops, such as strawberries were destroyed as a result.

3- Moving forward and mitigating the effects of climate change

Provisioning services are very important in rural communities' coping and adaptation strategies (Innes and Hickey, 2006). Many residents in Jabal Moussa rely on forest resources as safety nets to deal with stresses such as Covid-19, which has left many unemployed, and the economic crisis, which has depreciated the Lira's value, making everything from the supermarket prohibitively expensive, driving people toward agriculture. Forest products, such as fruits, make contributions to livelihood

diversification, an adapting and preemptive strategy that lessens communities' sensitivity to climate variability (Potschin et al., 2018). Despite climatic changes, complex cropping systems with numerous crop plants offer a continuous harvest of produce (Potschin et al, 2018).

The poorest and most vulnerable households depend extensively on ecosystem products for adaptation and coping strategies because they lack the financial means for collecting these products (Potschin et al., 2018). To make sure that ecosystems counteract climate change and assist people in adapting, management should first lessen threats to ES (for example, deforestation).

CHAPTER IV
RESEARCH QUESTION & OBJECTIVE

In-depth data on the effect of land management change on a vast array of ecosystem resources is critical in guiding land use and land management decisions. Nevertheless, empirical and quantitative data on the impact of land management on ecosystem resources is typically limited. The goal of this paper is therefore to map provisioning services focusing on agriculture production in biosphere reserves to assess whether there is a basis for conflict between residents and managers and challenges to the management team over access to natural resources. To achieve this goal, a research question was developed and addressed, which is "How can mapping food production locations enhance land management decisions in Jabal Moussa Biosphere Reserve to ensure long term ecosystem services provision?"

CHAPTER V
METHODOLOGY

Ecosystem services have progressively emerged as a major concept in environmental management worldwide with the goal of better-incorporating ecosystems into decision-making processes by taking into account human societies ' dependence on ecosystems (Braat, 2012).

ES evaluations are performed at the local to global levels (Jacobs et al., 2016) and are usually used for important, technological, or informative purposes (Laurans et al., 2013). Scientific developments, both theoretical and analytical, are continuously improving the ecosystem services methodology to improve its decision-making effectiveness. These scientific developments contribute to promoting the use of integrative methods such as mapping, modeling, and participatory approaches to analyze ecosystem services (Wei et al., 2017).

The supply relates to ecosystems ' ability to deliver sustainable services. This biophysical ability is the product of the environmental state and functioning and can be assimilated to a possible ecosystem service, which will only be transmitted if it is eventually used (Levrel et al., 2016). Therefore, in practice, supply assessment focuses on the ecosystem characteristics and processes involved in the production of ecosystem services (Kremen, 2005). The supply side can be measured as biophysical metrics, such as hectoliters of water or tons of carbon sequestered by ecosystems (Martín-López et al., 2014). The ecosystem services that are offered, and thus the trade-offs between those services, can vary with the different landscapes; hence, it’s important to examine the role of landscape in the identification of trade-offs. The goal of this study is to

assess the ES supply using spatial analysis in order to improve the management of Jabal Moussa.

The materials and data section of this paper provides a more detailed representation of sources of data and how they've been processed to be used, followed by a description of the process of selecting the key ES to be assessed, details and specifics of the methodological options utilized for the ES assessment, and an overlay of management practices and ES mapping.

Step 1: Materials and Data

The spatial analysis was carried out using ArcGIS software, on-layers (e.g., biosphere reserve boundaries) provided by experts in Jabal Moussa, and InVest, an open source model for mapping and valuing ecosystem services. At first, the Land Use and Land Cover (LULC) map was acquired from Lebanon's National Center for Remote Sensing (CNRS), however it did not have a sufficient resolution to the preferred scale (it had a 1:10,000 map scale; 10m detectable scale; 5m raster resolution); thus a higher resolution imagery (with 1:1,000 map scale; 1m detectable scale; 0.5m raster resolution) was obtained using Sentinel 2 data sets, as it has the best temporal, space, and spectrum resolution. It also has free, accessible, and open-source data. The CNRS LULC, on the other hand, was useful because it served as a starting point for identifying the most common LULC classes, and it did include some ground truthing. The Sentinel 2 imagery of Jabal Moussa was acquired from Google Earth Engine to be used in ArcGIS. The average of bands for the targeted month, August-2020, was obtained. The month of August-2020 was chosen because it provided a clear view of the vegetation (i.e. no cloud coverage) and because the crops chosen for this case study (i.e. tomato, strawberry, apples, etc.) are grown during this month. The

image was then re-classified, which entailed converting multi-band raster imagery into a single band raster with several categorical classes corresponding to different types of land use and land cover. The major land-use classes included agriculture, built-up areas, shrub-lands, bare land, woodland, and so on. As a result, the final resolution LULC map was created using Sentinel 2 imagery and the supervised classification technique, as well as data gathered from site visits, from which locals pinpointed the locations of the ES.

Step 2: Selection of primary ecosystem services in Jabal Moussa Biosphere Reserve

Since it is rich in biodiversity and supports a wide range of activities, Jabal Moussa Biosphere Reserve has the potential to provide a variety of ecosystem services with local benefits, such as food, water, ecotourism, carbon sequestration, and many others. In order to assess these ecosystem services, initially, 21 ecosystem services were identified to map, as shown in ***Table 5,*** which is more detailed in ***Appendix I***, with the help of local resources (i.e. brochures and websites), different stakeholders (i.e. APJM team members, scientists, tourists, mayors, and farmers), scientific reports and articles (A Walk Through Jabal Moussa, n.d.; Karam, 2016; and Sa et. al, 2017), and observations during site visits to Jabal Moussa. However, due to several constraints, including data availability, this paper focused solely on food provision, specifically strawberries, apples, and tomatoes, which were identified as one of the most important ES to the reserve's locals because they provide food and income, and for which ecological data were available and could be collected within time constraints. Furthermore, the Covid pandemic hampered data collection for this study, making it difficult to go on-site and interview a lot of people while maintaining social distance

and staying safe. Furthermore, only strawberries, apples, and tomatoes were chosen for the InVest "Crop Production Model" because sufficient quantities of these plants were grown to map in order for the model to run. The rest, such as (plum, peach, cucumber, beans, cherry, etc.), are not abundant enough to support the model.

Table 5: A list of all the Ecosystem Services available in Jabal Moussa Biosphere Reserve

Ecosystem Services Group	Ecosystem Services
Provisioning Services	Fruits, Vegetables, Bee Plants, Native Tree Nurseries, Woody Species Used for Afforestation Initiatives Implemented in Different Sites in Lebanon, Surface and Ground Water, Fodder and Grass for Pasture, Fuel, Timber, Fibers, and Other Raw Materials, Medicinal Plants, Genetic Resources, Plants Used for Cosmetics and Perfumery, and Poisonous Plants Used for Insecticides Against Home and Crop Pests
Regulating Services	Carbon Sequestration, Climate Regulation, and Disturbance Regulation, Water Purification from Vegetation Water Flow Regulation, Erosion Prevention and Maintaining Soil Fertility
Supporting Services	Lifecycle Maintenance, Habitat Maintenance, and Gene Pool Protection
Cultural Services	Ecotourism, Ornamental and Hedge Plants for Aesthetic and Recreational Values, Scientific and Educational Information, Historical and Spiritual Sites

Step 3: Mapping and Modeling the biophysical values of the key ecosystem services

1- LULC Map- Supervised Classification

There are many approaches for classifying imagery data; however, supervised and unsupervised techniques are the two most common methods for mapping LULC (Luo et al., 2017). The supervised technique is used in this paper because it generates more accurate classifications than the unsupervised

method (Bahadur et al., 2009). There are many statistics-based supervised classification algorithms; however, one of the most popular is the maximum likelihood classifier (Soni, 2011). The maximum likelihood classifier is widely used in remote sensing because it's quick, easy to adopt, allows for a straightforward interpretation of the results, and is accurate (Ren et al., 2019). The technique assumes that the stats for each LULC category for each band have a normal distribution and calculates the likelihood of each pixel belonging to a specific category (Ayele et al., 2018).

In order to perform the supervised classification, more than 50 training samples were chosen from the Sentinel 2 image by demarcating polygons that characterize different sample areas of the various land cover types to be classed. After developing the training sites, the maximum likelihood classifier was used to generate spectral signatures, which were then used to categorize all the pixels in the Sentinel 2 image.

The CNRS developed training samples for the predetermined LULC classes based on image analysis of Landsat images and knowledge and understanding of the study area, which served as a foundation for pinpointing some ES locations in the new map. More training samples, however, were collected in order to create a more detailed and accurate map with a better resolution. Moreover, field observations and data obtained from interviews with locals are required to overlap the supervised classification map to obtain the final one.

2- Ecosystem Services Mapping- Field Verification

Following the completion of the supervised classification map, it was time to collect data based on observations made during site visits and interviews with locals in order to improve the final map data and make it more accurate because digital visualization isn't enough to support the map; some ground-truthing is required as well.

During site visits, more than 15 different stakeholders (including APJM team members, farmers, mayors, women, youth, and village chiefs and mayors) assisted in mapping the various locations by pinpointing them on the ArcGIS web map. The farmers also mentioned the various agricultural plants they grow, such as strawberries, apples, tomatoes, plum, peach, cucumber, beans, cherry, and so on, which was helpful in mapping out the food supply.

3- Final Data Set

The field observations and data obtained from interviews with locals are required to overlap the supervised classification map to obtain the final one. Using ArcGIS' mask by attribute, the supervised classification map was overlapped with the web map to create the final map. This step assisted in the refinement of the E.S mapping, resulting in a more detailed and accurate map.

4- Land Management Strategies in Jabal Moussa

Obtaining the final map is insufficient to support management. It was also necessary to compare the APJM team's land management strategies to the map. Is agriculture, for example, not practiced in the core area, as claimed; however, it is first necessary to inquire about how the reserve is managed.

According to APJM team interviews, they try to implement various measures and practices in the Jabal Moussa that aim for the conservation, protection, and sustainable use of resources (such as biodiversity) as well as the restoration of degraded land in the various zones, but they are unable to address all of the zones. They stated the following:

1- In the core area: They allow hiking and grazing, but only on a specific trail (not beyond that trail). Agriculture, camping, fires, and hunting, on the other hand, are prohibited.

2- 2- In the buffer zone: they conserve as much as possible within the people's lands and raise awareness to stop charcoaling, shepherds' grazing, and so on.

3- In the transition area: they don't have any management strategies; they only communicate with village chiefs (mukhtars) and mayors (ra'ees baladiyeh) to raise awareness, and they include the local community in projects.

Step 4: Data Analysis

1- Overlay of Management Practices and E.S Mapping

Following the mapping of the biophysical values of the food provision ES, primarily strawberries, apples, and tomatoes, in the biosphere reserve's various zones, the InVest tool will be used to quantify the supply side of these ecosystem services, and an assessment will be performed to help evaluate any bad management practices occurring in any of these zones. The final map and the amount of food provision ES help determine whether management practices,

such as preventing agricultural practices in the core area, correspond to reality on the ground; this, in turn, contributes to the development of alternative management practices that can aid in sustainable growth.

2- InVest Model

The InVEST Crop Production Model, which is based on user supplied land cover info, is used to estimate crop yield for a set number of crops. The InVEST crop production model consists of two parts: a percentile-based yield model that covers 175 crops globally (based on sub-national and FAO datasets, expressed as tons/ha), and a regression-based model that considers fertilization rates for twelve crops (Crop Production, n.d.).

The percentile model will be used in this paper. This model will help in quantifying the yields of the food provision ES chosen for this study in specific locations across all of the zones of the biosphere reserve. The crop production percentile model will generate crop yields (a clipped observed-map) from the land-cover map (i.e. crop cover) of the selected ES [i.e. strawberries, apples, and tomatoes] (Rodriguez, 2020) that was generated by ArcGIS. The percentile yields are measured in metric tons/ year and then the values were converted to hectares (ha).

3- Overall Analysis

The final LULC map and the InVest model allow for a detailed analysis and investigation into how a different farming system or arrangement compares to existing systems in terms of overall production, and how crop intensification affects ES, both of which can help to improve the management of the biosphere

reserve and suggest approaches to meeting rising food demand while reducing the risk on ES.

CHAPTER VI
RESULTS

1- CNRS- LULC Map

Figure 18 depicts the LULC map obtained from the CNRS, which is not at the desired resolution scale and lacks specific information about where the food provision ES is located, which is needed for this study.

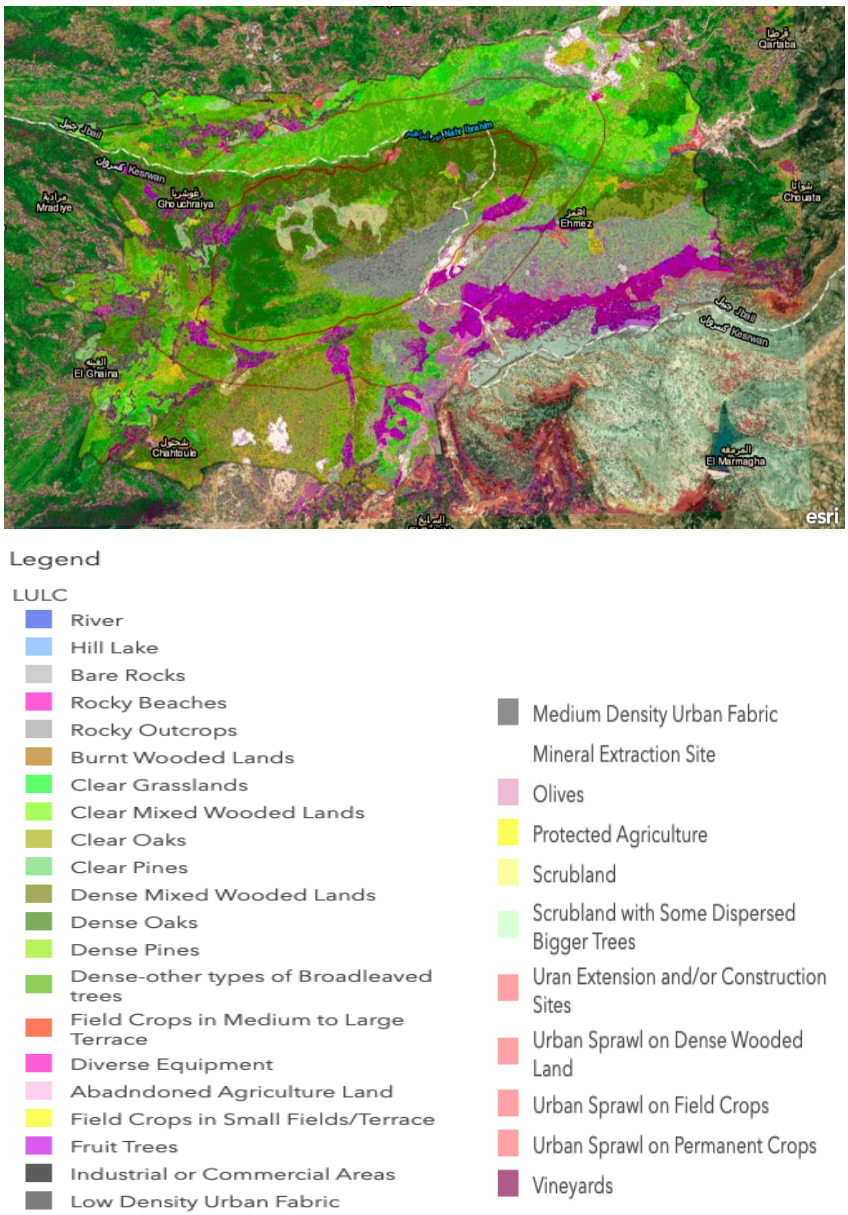

Figure 18: Lebanon's National Center for Remote Sensing (CNRS) Land Use/ Land Cover Map (2018)

2- ArcGIS map with supervised classification

Figure 19 depicts the supervised classification LULC map with the preferred resolution scale; however, this is not the final map. It still lacks data based on on-site visits and interviews with locals who pinpointed the exact locations of the fruits grown. To obtain an accurate and specific map, some ground-truthing is required in addition to digital visualization.

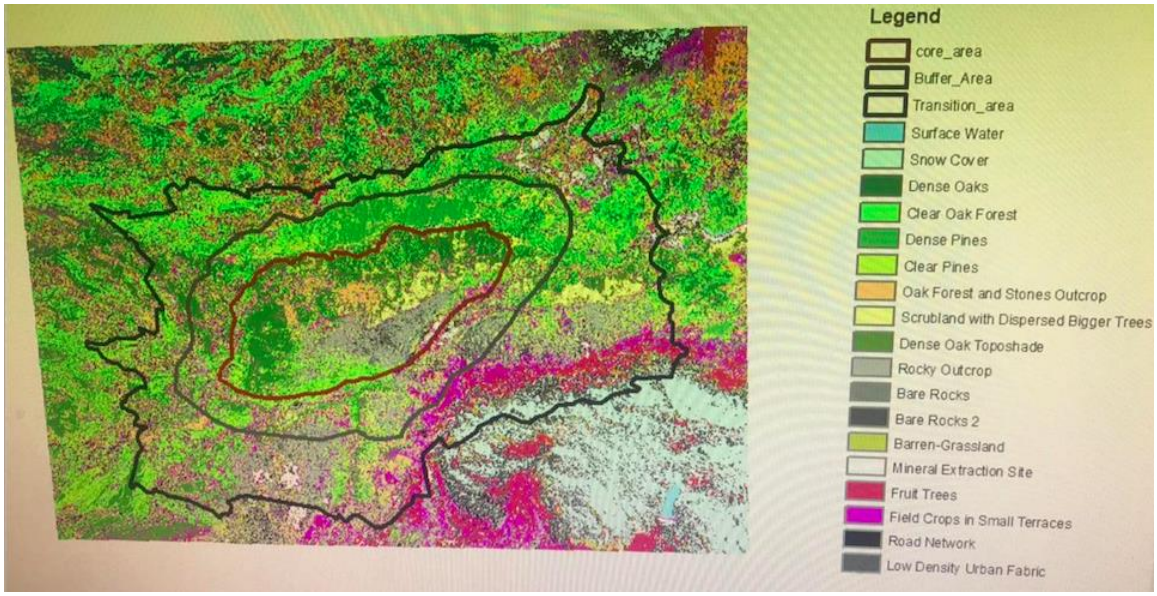

Figure 19: A high-resolution Supervised Classification LULC map

3- ArcGIS webmap with pinpoints of ecosystem service locations

Figure 20 depicts the pinpoints of various ecosystem services in multiple locations in Jabal Moussa, which were created using ArcGIS webmap and are based on locals' perception. Locals identified a total of 134 different ES locations, of which 24% are tomatoes, 19% are surface water, 18% are apple trees, 12% are quarries, 11% are beekeeping, 4% are strawberries, 3% are oaks, 2% are beans, peach, and pine each, and 1% are cherry trees, cucumbers, plum, and tree nursery each; however in this paper will only discuss the quantity and distribution of strawberries, apples, and tomatoes since their quantities are enough to run the InVest Model.

Figure 20: Using ArcGIS webmap, pinpoints of multiple locations in Jabal Moussa and their various ecosystem services

4- Final LULC map

Figure 21 depicts the final Land Use Land Cover map with supervised classification for Jabal Moussa Biosphere Reserve, which is an overlay of the maps in Figures 19 and 20, providing us with a more detailed, accurate, and high-resolution map. The final map depicts the precise distribution of strawberries, apples, and tomatoes across the biosphere reserve's various zones.

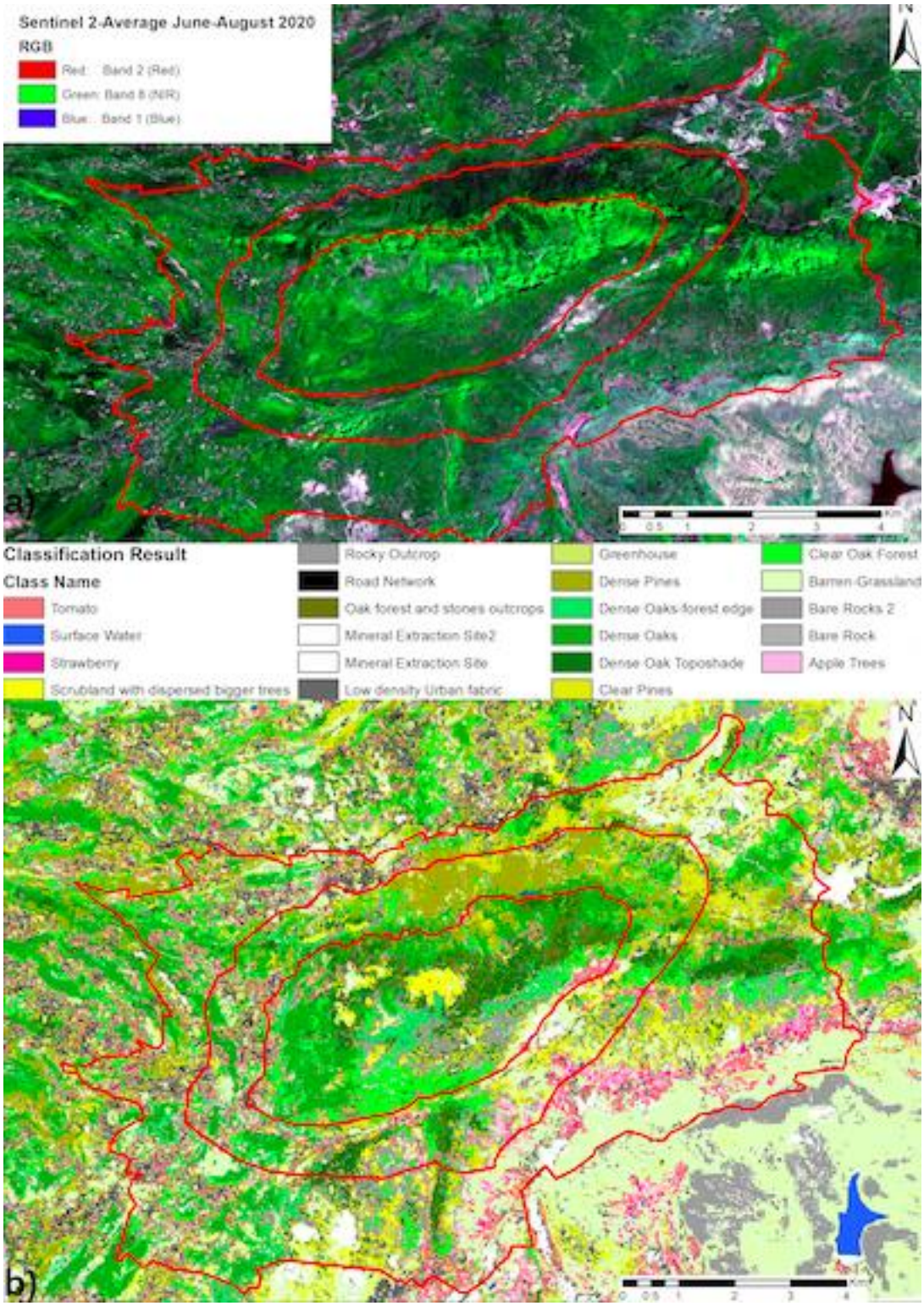

Figure 21: **Jabal Moussa Biosphere Reserve's final Land Use Land Cover map, with supervised classification (An overlay of Figures 19 and 20)**

5- InVest Model

Figures 22 and ***23*** show the amount of yield from the InVest Model for each crop used in this case study (strawberries, tomatoes, and apples) in each zone. The amount produced for each crop is calculated in metric tons per year and also converted to hectares. The core zone covers 1250 ha, the buffer covers 1700 ha, and the transition area covers 3550 ha, for a total of 6550 ha. As can be seen in the table below, 5.4% of tomatoes are grown in the core zone, 7% in the buffer zone, and 11.3% in the transition zone. In terms of apples, 1% is grown in the core zone, 2% in the buffer zone, and 2.4% in the transition zone. Strawberries account for 1.2% in the core zone, 2.2% in the buffer zone, and 3.5% in the transition zone. According to the findings, as a result of household settlement expansion and transitions from food to cash crops and fruit trees output, there is an increase in intensive agriculture in all three zones of the biosphere reserve (more abundantly in the buffer and transition area), causing biodiversity loss and land degradation. This is especially problematic in the core area because it contradicts the conservation rule that must be followed in this area.

Main Crops Produced	*Transition Area (Metric Tons/Year)*	*Transition Area (Hectare)*	*Buffer Area (Metric Tons/Year)*	*Buffer Area (Hectare)*	*Core Area (Metric Tons/Year)*	*Core Area (Hectare)*
Apple Yield	*1,710*	*85.5 ha (2.4%)*	*638*	*31.9 ha (2%)*	*210*	*10.5 ha (1%)*
Strawberry Yield	*2,494*	*124.7 ha (3.5%)*	*750*	*37.5ha (2.2%)*	*308*	*15.4 ha (1.2%)*
Tomato Yield	*8,021*	*401.05ha (11.3%)*	*2,440*	*122 ha (7%)*	*1,351*	*67.55 ha (5.4%)*
Grand Total	*12,226*	*611.25ha (17.2%)*	*3,828*	*191.4ha (11.2%)*	*1,868*	*93.35 ha (7.6%)*

Figure 22: The Invest model output values measured in metric tons/ year and hectares

Residents are prohibited from logging, grazing, intensive agriculture, and picking wild herbs, but this is not the case for agricultural production, as shown above. Furthermore, these practices became illegal following the most recent legislation and the ban on the use of forest resources associated with the status of the Protected Forest and Biosphere Reserve (Karam, 2016). However, because it is their private land and they are free to do whatever they want on it, not all locals listen and follow rules, resulting in land fragmentation, low inputs, and low financial and agricultural outputs (El-Kholei, 2012). This calls for action to prevent farmers from intensively growing crops in the different areas.

As a result, sustainable development possibilities must be considered in order to enhance or conserve certain ES in ways that minimize negative trade-offs or offer

positive synergies with other ES via agro-biodiversity integration and improved agricultural techniques. Appropriate changes in diverse agricultural practices, as well as the implementation of a more integral approach to agro-biodiversity and ecosystem practices, must be implemented to recompense for declining trends in ES. Preferring people living near forests in farming system methods, on the other hand, will encourage potential ecological sustainability and help to maintain numerous ES as long as people's needs are met.

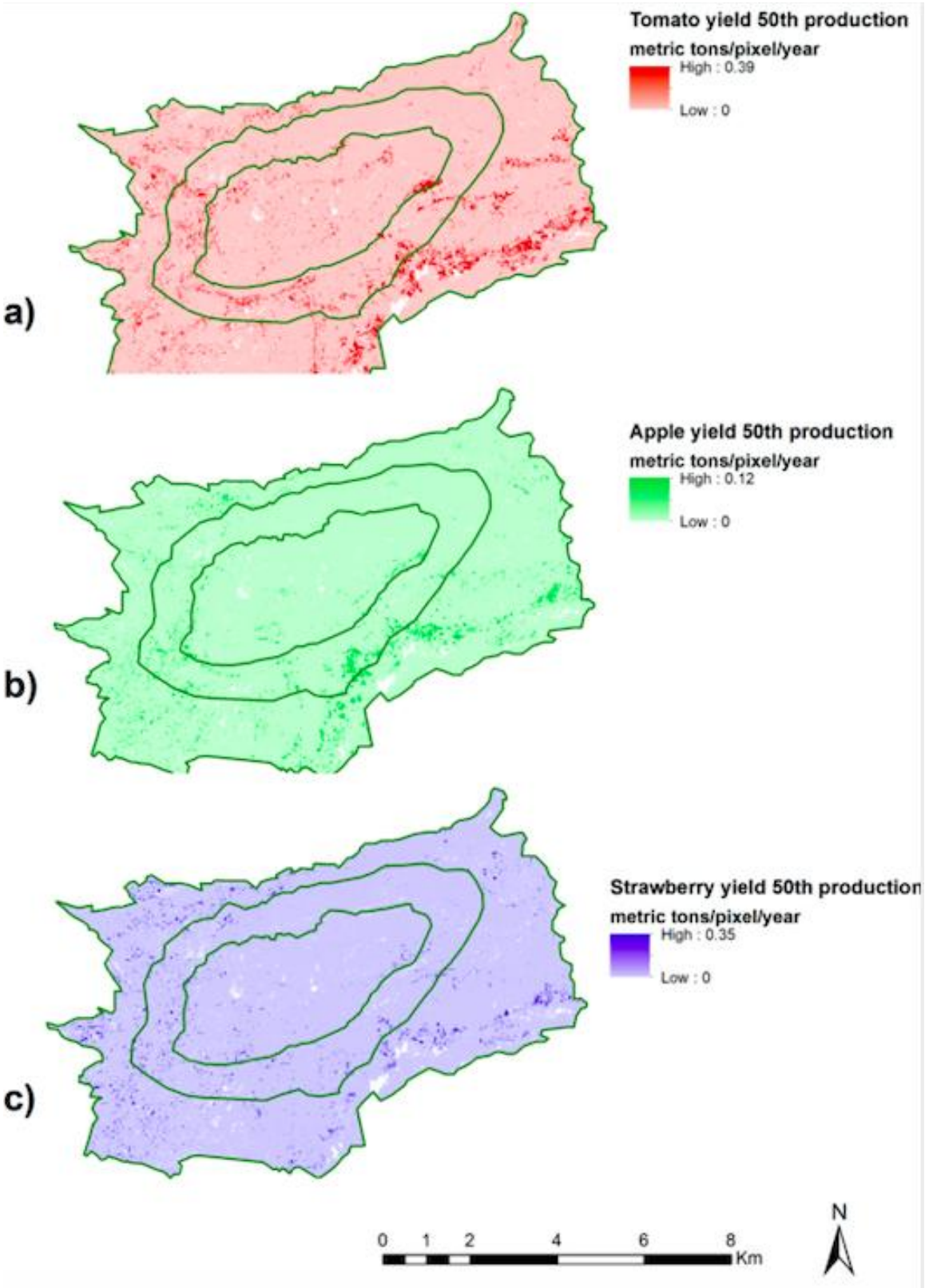

Figure 23: The percentile maps of the InVEST Crop Production models

CHAPTER VII
DISCUSSION, RECOMMENDATIONS, AND CONCLUSION

A- Discussion

Jabal Moussa Biosphere Reserve provides benefits to locals in the form of ecotourism and recreational opportunities, grazing, food, handcrafts, and some beekeeping. However, climatic changes and anthropogenic pressure can have a negative impact on the natural restoration of important plant species of great economic value. Furthermore, JMBR offers indirect non-marketed services like biodiversity conservation and wildlife hosting, soil protection and erosion control, water regulation, carbon sequestration, and so on. However, there have been conflicts between the biosphere reserve managers and the locals over access to natural resources (ex: logging; hunting; picking herbs); especially in the core area.

The goods and services chosen for this evaluation were food (i.e. tomato, strawberry, and apples). These goods and services have been chosen in accordance with their economic, environmental, and social value to the local population. Such goods and services can be competitive and provide substantial revenues for local users. The food provision ES are being mapped in order to improve land management decisions in Jabal Moussa Biosphere Reserve and ensure long-term sustainability. Structured interviews, mapping, and modeling with selected stakeholders were used to evaluate each farming system's contribution to ES provisioning, including its trends.

It is worth noting that the evaluation of ecosystem services in biosphere reserves can vary greatly. Biosphere reserves have three zones, and there’s a need to understand how ecosystem services can be affected differently in each of these areas. Based on the

results of the research, agricultural practices occur across all three zones of the biosphere reserve.

According to UNESCO's biosphere reserve concept, core areas should be absent of agricultural produce, which is not the case in Jabal Moussa. In the core area, three crops (strawberries, apples, and tomatoes) are grown densely, destroying the biological diversity of natural terrestrial ecosystems. A land management recommendation would be to remove crop production and replace it with herb production by the same farmers. Herb production must occur in the core area because it is consistent with the core area's preservation concept. Growing herbs enables farmers to produce better, safer products, while supporting biodiversity. Farmers will be able to provide resources and habitats for native wildlife thanks to the conservation measures they will put in place. Many farmers believe that farms that endorse conservation will hurt their profit margins. Many preservation efforts, on the other hand, are long-term investments in the local area. Long-term expenses can be minimized by actions like reducing plant substitute, water and fertilizer use, and soil degradation. Farmers can incorporate conservation into their farming by growing a native species yard, incorporating flowers into crop rows for pollinating insects, and planting a windbreak (i.e., rows of native conifers or deciduous shrubs that protect crops from wind and prevent soil erosion).

In comparison to the core area, the three crops are grown more abundantly in the buffer and transition zones. The buffer zone, which is adjacent to the core area also seeks to use an ecosystem-based approach and environmental concepts to encourage sustainable development; hence farmers should consider growing rain-fed and harvest crops in the buffer zone to replace the three assessed crops. To ensure sustainable

development, it’s also necessary to promote and maintain ecosystem services in the buffer zone.

Agriculture will be permitted in the transition zone, but only with the goal of transitioning to sustainable agricultural practices. Farmers in this zone must consider sustainable practices such as no-till agriculture, eliminating pesticide use in favor of complementary wild plants that repel pests, using plants to fix nitrogen in the soil, and using seasonal crop rotation. These practices will help framers while reducing the impact on the reserve's natural systems, which will help to support and expand biodiversity. Traditional farming techniques must be replaced with low-tech alternatives in order to improve socioeconomic and environmental benefits.

Farming systems that are more diverse and less cultivated offer greater ES, whereas land users are more likely to practice less diversified farming methods to increase food supply at the cost of other ES. Therefore, diversified farming methods must be considered in order to enhance or conserve particular ES in ways that minimize their negative trade - offs.

B- Recommendations

1- Provide Incentives to Farmers by Renting Out their Land or Swapping it for Another Piece of Land

The APJM must provide incentives for farmers, such as renting their land at a profit because they are giving up this land, which provides them with produce to sell and profit from, or purchasing the land from the farmers to end agriculture in the core area. Moreover, there must be an environmental management scheme in place to incentivize landowners to manage their environment, thereby conserving

the biosphere reserve. Because the APJM has no control over what happens outside the core area because it is all privatized land, this is an effective way to persuade locals to stop destroying and start protecting the environment.

Furthermore, farmers sell tomatoes for 10,000 LBP/ kg and the strawberries for 15-25000 LBP / kg and the apples for 7-15000 LBP / kg. If they only sell half of their produce, farmers will earn 94,000,000,000 LBP, which is far more than the reserve earns from entrance fees on hiking, as shown in table 4. As a result, the managers must find a way to pay off this amount (for example, paying for seeds and fertilizers) in order to persuade farmers to switch or stop producing these crops.

2- Involvement of farmers in Decision-Making

The APJM must execute a stronger participatory decision-making approach in Jabal Moussa so that the farmers can support the APJM in decision-making while also highlighting their needs. The APJM must promote the management process through dialogue with farmers and ensure that their interests are consistent with a predetermined understanding of sustainable growth, which, if not resolved, will pose several challenges to the effective management of the biosphere reserve. The APJM should do more to empower local communities and use their unique knowledge, as well as actively involve farmers in research co-design to shift their way of thinking toward more sustainable agriculture. Therefore there's an urgent need for a more progressive multi-stakeholder management approach to effectively implement the triple biosphere reserve functions, as well as for local community involvement in decision-making (IUCN 1995; Price 2002).

It is necessary that farmers collaborate with the APJM in order to address the impact of present, and future land-use planning decisions. This helps with landscape management and strategic planning discussions for the conservation of the ecosystem. (Mitchell et al., 2015) It also strengthens community engagement by providing information on how land-use practices and landscape structural changes are likely to impact biodiversity and ecosystem services in Jabal Moussa. It also strengthens awareness about biodiversity and ecological resources in the landscape; emphasizes the importance of protecting and linking natural environments; creates a collective and more sustainable view of the biosphere reserve territory; optimizes the benefits of scientific research through collaboration and stakeholder engagement.

3- Funds to Support Sustainable Agriculture

Additionally, NGOs, private sectors, and ministries can assist farmers by providing financial assistance in order for them to continue farming because, as the value of the dollar rises and the Lebanese Lira falls, the prices of pesticides rise, and farmers will no longer be able to afford to purchase pesticides, and farmers rely on farming for sustenance and survival. The APJM can act as a middleman, informing these organizations about which farmers require assistance, or it can assist farmers in locating additional funds from other sources.

There must also be financing projects that support farmer's activities as well as make sure that decision-makers receive financial and technical assistance in executing agricultural development plans.

4- Cooperatives for Agricultural Production

Furthermore, farmers from Jabal Moussa's seven surrounding villages must form a cooperative. Cooperatives, for example, can assist farmers in taking advantage of economies of scale by reducing their cost of obtaining inputs or employing services like transportation and storage. Farmers can also improve service and product quality and minimize risk by joining agricultural coops. They might even socially and economically empower their participants by engaging them in decision making processes that result in more rural job opportunities or allow them to become more resilient to environmental and economic shocks.

The APJM must assist in teaching farmers the precepts of group management and community-organizing skills, as well as individual management skills, in order to assist the community, particularly the poor or vulnerable sections, in structuring itself for development. Understanding the frameworks, rules, bylaws, and roles will assist farmers in planning, implementing, and monitoring their programs, as well as performing this new position efficiently.

5- Promote Sustainable Agricultural Practices & Innovation within the Jabal Moussa Biosphere Reserve

The APJM must promote agricultural innovation by disseminating locally adapted techniques such as pesticide use, agricultural mechanization, irrigation systems, training to improve agricultural practices, and pesticide use, all of which will boost production in the buffer and transition zone.

C. Conclusion

This paper attempted to determine how mapping food production locations and determining total yield can improve land management decisions in Jabal Moussa Biosphere Reserve to ensure long-term ecosystem service provision.

The paper used ArcGIS and the InVest tool to map and calculate the total yield of strawberries, tomatoes, and apples, as these ecosystem services are very important to the reserve's residents because they provide food and income, and for which ecological data were available and could be collected within time constraints. Furthermore, only strawberries, apples, and tomatoes were chosen for the InVest "Crop Production Model" because sufficient quantities of these crops were grown to run the model.

The findings revealed that intensive agriculture (particularly tomato cultivation) is practiced on privately owned land in the core area, which is not allowed. As a result, this paper proposed some recommendations to help better manage agriculture for long-term sustainability in Jabal Moussa. These recommendations included farmer incentives, a participatory decision-making approach, funds, cooperatives, agriculture innovation, and technical assistance.

These two tools (i.e. ArcGIS and InVest) for mapping and quantifying ecosystem services are transferable to other similar areas in Lebanon, such as the Shouf Biosphere Reserve, where data on the location and quantity of crops is also lacking.

Moreover, there were numerous challenges encountered in collecting data for this study, the majority of which stemmed from the Covid pandemic,

making it difficult to go on-site and interview a large number of people while maintaining social distance and staying safe.

Furthermore, as we all know, no research is perfect; not many ecosystem services were mapped due to a lack of data availability; if more data had been available, it would have been much better to provide more recommendations to different practices in order to better manage the biosphere reserve.

To sum up, if the APJM implements some of the recommendations made in this study, it will undoubtedly improve many of its management practices in order to have a long-term and sustainable food provision ES.

Appendix I

Ecosystem Services Group	Ecosystem Services	Examples
Provisioning Services	Fruits	Tomato, Sunflower, Squash, Cucumber, Peach, Plum, Pear, Apple, Pomme Grenade, Grapes, Ficus Carica "Teen", Prunus Mahaleb "Mahaleb Cherry", Pumpkin, Olive, Mulberry, Apricot, Strawberry, Walnut, Maize, Kiwi, Diospyros Kaki "Kharma" , Lemon, Almond, Rhus Coriaria "Sumach
	Vegetables	Green Beans, Red Beans, Cauliflower, Cabbage, Potato, Radish, Onion, Lettuce, Mountain Greens locally referred to as "**Slieka**" (e.g., Centaurea Calcitrapa, Cichorium Intybus, Eryngium Creticum, Malva sp., Portulaca Oleracea) , Gundelia Tournefottii "**A'kub**", Ceratonia Siliqua "**Kharroub**" (used for extracting Molasses "**Debs**"), Origanum Syriacum "**Za'atar**", Eggplant, Parsley, Mint, Arugula "**Rocca**", Carrots, Coriandrum Sativum "**Kezebra**", Armenian Cucumber **"Mekte"**, Herbarium (Dried Plants)
	Bee Plants	Centaurea Calcitrapa, Dittrichia Viscosa, Eryngium Creticum, Melissa Officinalis, Origanum Syriacum, Salvia Fruticosa, and Prunus sp.
	Native Tree Nurseries	Umbrella Pine, Three-Lobed Apple **"Toufah Barri"**, Syrian Pear **"Njas Barri"**, Spanish Broom **"Wizzal"**, Oriental Strawberry Tree **"El Kattlab"**, Oriental Almond **"Loz Sharki"**,Mediterranean Cypress **" Srour El Moutawasset"**, Manna Ash **"Maran Zahri"**, Laurel **"Ghar"**, Kermes Oak **"Sindiyan"**, Cyprus Oak **"A'afes"**, Common Hawthorn **"Za'arour"** , Calabrian Pine **"Sanawbar Barri"**
	Woody Species Used for Afforestation Initiatives Implemented in Different Sites in Lebanon	Prunus sp. and Ceratonia Siliqua
	Surface Water and Ground Water	Streams, Lakes, River, and Ground Water Aquifers
	Fodder and Grass for Pasture	Bituminaria, Bituminosa, Cynodon Dactylon, Hordeum Bulbosum (mainly for goats), Green Wild Grass and Leafy Species (usually available during spring time for all livestock), Alyssum Murale "**Al Wassen Al Hitan**", Fibigia Clypeata "**Hashishat Al Kounat**", Lathyrus Digitatus "**Jalban Tawil**", Medicago Lupulina "**Fessat Janjaliya**", Ononis natrix "**Shobrok Tha'abani**", Trifolium Physodes "**Nafel Mathani**", Trifolium Squarosum "**Nafel Mahreshef**", Briza Maxima "**Kifat Al Sheikh**", Bromus Syriacus "**E'elaf Souri**", Bromus Tectorum "**Danka**", Bromus Tomentellus

		"**E'elaf Labidi**", Dactylis Glomerata "**Osbai'it Motajamia'a**", Hyparrhenia Hirta Pubescens "**Sakhbar Azeb**", Lolium Perenne "**Hashishat Al Faras**", Melica Ciliaca Laxiflora "**Malikat Mahdaba**", Phleum Montanum "**A'asawiye Jabaliye**", Poa Bulbosa "**Basliye**"
	Fuel	Firewood from all trees except the Juniperus Drupacea, Juniperus Oxycedrus, Platanus Orientali, Populus Nigra, Salix Libani, Pinus Brutia, and Prunus sp. because they produce low quality charcoal
	Timber, Fibers, and Other Raw Materials	Q. Calliprinos for timber production, Alnus Orientalis for agricultural tools, Arbutus Unedo for Dyes, Rhus Coriaria for tannin and dyes, Spartium Junceum for brooms, coarse fabrics, and dyes, Prunus sp. for walking sticks, Calicotome Villosa, Ruscus Aculeatus, and Typha domingensis for brooms and rags
	Medicinal Plants	Alcea Setosa "**Khatmiya**", Ecballium Elaterium, Malva sp., Matricaria Chamomilla, Micromeria sp., Viola Odorata, Sumach, Pistacia Mutica "**Chuccair**", Pistacia Palaestina "**Batm**", Coriandrum Sativum "**Kezebra**", Foeniculum Vulgare "**Shammar**", Prangos Asperula "**Forish Al Dabe'e**", Arisarum Vulgare Veslingii "**Kabu'u Al Rahib**", Aristolochia Altissima "**Zarawand Shahik**",Dryopteris Pallida Libanotica "**Shamshar Shahib**", Ceterach Officinarum "**Hashishat Al Dahab**", Achillea Tanacetifolia "**Hashishat Al Shaffa**", Artemisia Verlotorum "**Shyh Faraluh**", Bellis Perennis "**Bilays Mu'umar**", Centaurea Solstitiais Solstitialis "**Kantryoun Mdari**", Cnicus Benedictus "**Shawkat Mubaraka**", Conyza (Erigeron) Bonariensis "**Kouniza Bons Iris**", Conyza (Erigeron) Canadense "**Arigaron Kanadi**", Conyza (Erigeron) Naudinii "**Arigaron Nudan**", Eupatorium Cannabinum Indivisum "**Khad Al Benet**", Inula Vulgaris "**Toyoun Al Thabab**", Matricaria Chamomilla "**Babounej**", Ptilostemon Chamaepeuce "**Sanawbar Al Ared**", Ptilostemon Diacantha Diacantha "**Btaylstamun**", Pulicaria Dysenterica "**Ra'ara'a Ayoub**", Senecio Vulgaris "**Babounej Al Tayr**", Tussilago Farfara "**Hachichat Al Soua'al**", Xanthium Strumarium "**Shbit Dod Al Sa'alat**" , Symphytum Palaestinum "**Lisan Al Torr**", Capsella Bursa-Pastoris "**Jrab Al Ra'ai**", Cardamine Hirsute "**Krat Al Karoum**", Eruca Vesicaria "**Rocket Mazrou'a**", Lepidium Hirtum Microstylum "**E'esab Klimi**", Nasturium Officinale "**Krat**", Sisymbrium Officinale "**Samarat Tobiya**", Sambucus Nigra "**Bilsan**", Paronychia Argentea "**Harbat Fodi**", Saponaria Officinalis "**Saboune Tobiya**", Chenopodium Ambrosoides "**Mati**", Chenopodium Botrys "**Sormok E'eter**", Convolvulus Althaeoides "**Lblab Al Khatmiye**", Convolvulus Scammonia "**Sakmoumiya**", Cornus Qustralis "**Kraniyah Janoubiya**", Bryonia Multiflora "**E'einab Al Hayat**", Arceuthos Drupacea "**Defran**", Cyperus Longus "**Sa'ad Tawil**", Cyperus Rotundus "**Sa'ad Mdawar**", Tamus Communis "**Jarmou'u Shae'e**", Equisetum Ramosissimum "**Namss",** Equisetum Telmateia "**Kenbath Mortafe'e**", Arbutus Unedo "**To'omat Al Hamra**", Euphorbia Peplis "**Zerek",** Euphorbia Peplus "**Forfokh**", Astragalus Gummifer "**Kathira'a**", Colutea Cilicica "**Sanaa Katheb**", Coronilla Varia Libanotica "**Aklil Lebnen**", Melilotus Italica "**Handakouk Italy**", Ononis Apinosa Leiosperma

		"**Shobrok Shae'ek**", Spartium Junceum "**Wzal**", Trifolium Repens "**Nafel Zahef**", Vicia Narbonensis "**Fol Al Jayad**", Quercus Infectoria "**Maloul**", Blackstonia Perfoliata "**Blackstonia Makhrouka**", Erodium Moschatum "**Musky**", Geranium Molle "Gharouk **Layen**", Geranium Purpureum "**Gharouk Orjouwani**", Geranium Robertianum "**Ibrat Al Rai'i**", Juglans Regia "**Joz**", Juncus Effusus "**Asel Monbaset**" , Eremostachys Laciniata "**Hajenbel Msharshar**", Lamium Purpureum "**Lamyoun Orjouwani**", Lavandula Stoechas "**Lavendre**", Lycopus Europaeus "**Frasiyoun Al Maa**", Melissa Officinalis "**Ternjan Tobbi**", Mentha Aquatica "**Na'ana'a Al Maa**", Mentha Microphylla "**Na'ana'a Saghir Al Warak**", Origanum Ehrenbergii "**Za'atar Ramli**", Origanum libanoticum "**Za'atar Lebnen**", Origanum Syriacum "**Za'atar**", Salvia fruticosa Libanotica "**Kasi'in Lebnan**", Salvia Verbenaca "**Kawisa Hamamiya**", Teucrium Polium "**Jaada**", Laurus nobilis "**Ghar Shai'i**", Asparagus acutifolius " **Halyoun Had Warak**", Asphodelus Microcarpus "**Ishras**", Colchicum Steveni "**Sornjan Stivan**", Lilium Candidum "**Zonbok Mar Youssef**", Ruscus Aculeatus "**E'enab Barri**", Malva Sylvestris "**Khabiza Lil Zeenat**", Myrtus Communis "**A'as Shai'i**", Phillyrea Media "**Berzat**", Epilobium Parviflorum Menthoides "**Nad Saghir Al Zaher**", Epilobium Tetragonum "**Thanab Alco**t", Limodorum Abortivum **"Limodorem Khadij"**, Papaver Dubium Laevigatum **"Kheshkhash Mahir",** Passiflora Caerulea **"Sa'at Zarka"**, Plantago Lanceolate **"Lisan Al Hamal Sinani",** Plantago Major **"Lisan Al Hamal Kabir",** Arundo Donax **"Kasseb Shai'i",** Portulaca Oleracea **"Bakle",** Samolus Valerand **"Labin Al Maa",** Adianthum Capillus-Veneris **"Kezbarra Al Bir"**, Anemone Coronaria Cyanea **"Shakaik Zarkaa",** Anemone Co.r Phoenicea **"Shakaik Hamra",** Ficaria Grandiflora **"Tiniye Kabira Al Zaher",** Rhamnus Alaternus **"Zakrin Al Jered",** Crataegus Azarolus **"Za'arour Shai'i",** Crataegus Monogyna **"Za'arour Ahadi Al Kalam"**, Geum Urbanum **"Jouyoum Al Hawader"**, Rosa Canina **"Wared Al Kilab"**,Galium Verum **"Ghaliyoum Hakiki",** Digitalis Ferruginea **"Dejtal Al Hadid"**, Solanum Dulcamara **"E'enab Al Dib ",** Styrax Officinalis **"Hoz",** Tilia Silvestris Intermedia Ghbali **"Zayzafoun Harji",** Urtica Dioica **"Kouris Kabir",** Urtica Urens **" Kouris Mohrak",** Valeriana Dioscoridis **"Nardin"** , Verbena Officinalis **"Rai'i Al Hamam"**, Viola Odorata **"Banafsaji O'oter"**
	Genetic Resources	Crop Wild Relatives of Hordeum, Aegilops, Avena, Pisum, and Vicia, some fruit trees (ex: Prunus sp.) that are frequently used for seed harvesting in nurseries as rootstocks for local cultivated varieties of Plum and Almonds, and Wild Pyrus Trees implanted by local varieties to produce edible fruits for shepherds and other local inhabitants
	Plants Used for Cosmetics and Perfumery	Aurus Nobilis, Lilium Candidum, Myrtus Communis, Narcissus Tazetta, Viola Odorata, Juniperus Drupacea, Juniperus Oxycedrus, and Pinus Brutia

	Poisonous Plants Used for Insecticides Against Home and Crop Pests	Myrtus Communis, Laurus Nobilis, Origanum Syriacum, Salvia Sclarea, and Salvia Fruticosa
Regulating and Supporting Services	Carbon Sequestration, Climate Regulation, and Disturbance Regulation	All the trees in JMBR sequester carbon and reduce noise pollution (ex: tall specimens of Oriental Plane **"Platanus Orientalis"**, small trees and shrub species, such as, Salix Orientalis, Alnus Orientalis, Wild Almond **"Amygdalus Orientalis"**, and the Mahlab **"Prunus Mahaleb"** ,Kermes Oak "**Quercus Calliprinos"**, Storax "**Styrax Officinalis"**, Terebinth **"Pistacia Palaestina"**, Hawthorn **"Crataegus Monogyna and Crataegus Azarolus"**,Prickly Juniper **"Juniperus Oxycedrus and Rosa Canina"**, rare and endemic Threelobed Apple **"Malus Trilobata"** , Chequer Tree **"Sorbus Torminalis"**, Oak Species, such as Quercus Calliprinos, Quercus Infectoria, and Quercus Cerris, Syrian Juniper **"Juniperus Drupacea"** , Manna Ash **"Fraxinus Ornus"**, Taurus Maple **"Acer Tauricolum"**, Hop-Horn Beam **"Ostrya Carpinifolia"**, dense pine forest **"Pinus Brutia"**, broadleaved species in Coniferous Forest (ex: Arbutus Andrachne, Ceratonia Siliqua, Quercus Infectoria, Laurus Nobilis, Phillyrea Latifolia, Styrax Officinalis, Cercis Siliquastrum, Acer Syriacum) , as well as many other trees. Moreover, JMBR plays an important role in Mount Lebanon's water cycle, influencing precipitation and climate regimes as well as modulating runoff regimes.
	Water Purification from Vegetation Water Flow Regulation	The vegetation and soils in Jabal Moussa Biosphere Reserve capture rainfall and regulate the gradual water flow and sediments downstream, fertilizing agricultural plains and replenishing ground water aquifers and rivers in lowland-areas.
	Erosion Prevention and Maintaining Soil Fertility	Promoting soil health and fertility through the use of green manure or the growth of legumes for nitrogen fixation; the use of micro-dose fertilizer applications to regenerate losses thru plant-uptake as well as other processes; and diminish losses thru leaching far below the crop root zone thru enhanced nutrient and water applications
	Lifecycle Maintenance, Habitat Maintenance, and Gene Pool Protection	Habitats include: Caves, Rocky Landscapes, Grasslands, Rivers, and Riparian Habitat
Cultural Services	Ecotourism	15 Hiking Trails, Bed & Breakfeast, and Guest Houses
	Ornamental and Hedge Plants for Aesthetic and Recreational Values	Amaranthus Caudatus "**Eurif Aldiyk**", Rhododendron Ponticum, Lilium Candidum, Paeonia Kesrouanensis, Cyclamen sp., Juniperus Drupacea, Juniperus Oxycedrus, Ceratonia Siliqua, Rhododendron Ponticum Brachycarpum "**Al Bakil**", Ononis Viscose Breviflora "**Shobrok Saghir**", Geranium Tuberosum "**Gharnouk A'askawli**", Iris Florentina "**Sawsan Abyad**", Iris

		Histrio "**Sawsan Moukalad**", Fritillaria Acmopetala "**A'arar Had Al Botlat**", Fritillaria Alfreda Ghini "**A'arar Al Farid**", Ornithogalum Plathyphyllum "**Sasel A'arid**", Pushkinia Scilloides Libanotica "**Pushkinia Lebnen**", Oxalis Articulata "**Hmad Ahmar**", Paeonia Kesrouanensis "**Wadeh Kesrouan**", Paeonia Mascula "**Wadeh Marjani**", Populus Nigra "**Hawr Aswad**", Cestrum Parquii "**Koloniya**", Lantana Camara "**Rai'i Bourtoukali wa Zaher**", Lantana Viburnoides "**Rai'i Laylaki Mouzher**"
	Scientific and Educational Information	Native Tree Nursuries, Rare species to discover, and "Tabsoun Tabsoun", a series of children's adventure novels, published by Najib Kassar, with the rock hyrax (i.e. Tabsoun) being the central protagonist. The aim of the series is to raise children's awareness about the importance of the environment and to present them to the plants and animals in Jabal Moussa through a thrilling and amusing adventure with Tabsoun
	Historical and Spiritual Sites	Roman Stairs, Old Houses and Cisterns, Qornet El Deir, Cross-Site, Stele depicting Phoenician God Adonis, Hadrian's Inscription, El Byut, Roman Tomb, Roman Basin, Ottoman Watermill, Ottoman bridge, Limestone Kiln, Old Churches and Adonis River

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