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Ecosystem Services of the Argan Forest, the Current State and Trends

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

The arganeraie is a traditional agro-ecosystem based on a balance between resources and human exploitation. The argan tree plays an important role in the subsistence of the people of the south east region of Morocco through its multi-use (its ecosystem services), and its role in fighting against desertification. Currently, the threat of the argan forest deterioration is a major concern both for local population, for planers and for scientists. There have indeed several decades a reduction of tree cover, both in area occupied and density of trees and therefore the associated ecosystem services. With this concern, we will study firstly, the space of the argan tree by trying to identify the ecosystem services and the key indicators of stress in this space. Then, we will assess the current state and likely future state of argan forest ecosystem services relative to anthropogenic pressure and climate change. The information found will be the basis of the "Integrative Science for Society and the Environment" (ISSE) model developed by ILTER in 2007. This Meta paper is not based on original evidence, but on existing studies.

Keywords: Argan forest; ecosystem services; ISSE Model.

1. INTRODUCTION

The conjugated impacts of climate change and human pressure are responsible for extinction rates leading to the sixth mass extinction of global biodiversity [1]. Over the past 50 years, people have changed ecosystems more than at any time in human history [2]. Arid and semi arid

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lands are among the most vulnerable ecosystems. The argan forest ecosystem is one of these ecosystems. Original Moroccan forest is located in semi arid region of Morocco. It is declared as a biosphere reserve of southern Morocco and recognized by UNESCO in 1998; It offers a rich biodiversity that supports a large number of ecosystem services. The argan tree survives on poor and dry soils. It is endangered mainly since its superficies are constantly shrinking and the tree density is permanently decreasing. In fact, in the early twentieth century, the global surface of argan forest was estimated at 1.5 million hectares [3]. For a century, the forest has experienced a loss of half of its surface [4]. Thus, between 1918 and 1924, the rate was destroyed around 2000 hectares / year [5]. With the Second World War (1939-1945), the destruction process has increased. The cultivated area was around 400 000 hectares [6]. The clearing of Argan trees and removal of floristic cortege are the main causes of the regression of the argan area and especially trees density [7]. The short term management of these resources accelerates this regression rate, which requires a long term vision on the socio-ecological argan groves. In order to do this long term management, we used the conceptual model "Integrated Science for Society and the Environment (ISSE)" developed by the International Long-Term Ecological Research Network (ILTER) in 2007. The paper identifies, firstly, the ecosystem services, and providing an understanding of the dynamics between ecosystem structure and function in context of climate change. This later plus the overgrazing, the collecting nuts, the timber extraction, the expansion of agriculture and the urbanization affect the loss of trees [8]. Based mainly on bibliographic data we will firstly, identify ecosystem services essentials to the success of socio-economical development and secondly, we will assess the state and the trends of ecosystem services of the argan forest.

2. MATERIALS AND METHODOLOGIES

2.1 Study Area

Argania spinosa L. is one of the endemic oldest forest trees with multiple values and uses [9]. The ecosystem of the argan tree has a geographical area of 950 000 ha of which 80% is located in the Souss Massa Draa region (Morocco). UNESCO and the Moroccan State classified the argan forest as "Biosphere Reserve" in 1998. This reserve extends from the coastline to the north of Essaouira to the south of Agadir and is limited by the Taroudant province in the east (Fig. 1). It is widely distributed along southern west of Morocco and it covered about 950 000 ha in 2010 [10], it occupies 7% of the forest area in Morocco [11], representing 6 provinces: Agadir Ida Outanane, Taroudant, Tiznit, Chtouka Aït Baha, Sidi Ifni and Essaouira.

The population is around 3 million people predominantly Amazigh (Berber) with almost half, 1.3 million people are directly dependent on the exploitation of the argan tree [12]. It tolerates heat and drought; it can survive in arid environments, even under severe stress conditions [9].

2.2 Methodology

The model used “Integrative Science for Society and the Environment” is interesting, and could allow to study the status of ecosystem services in the Arganeraie. This could be a good contribution to better management in the area, by linking social and biophysics components. Turner et al. 2003 was conceptualizing human-environment system, and then Palmer et al., [13] called ‘Socio-ecological system’. In 2007, the International Long-Term Ecological Research Network (ILTER) developed a conceptual model "Integrated Science for Society and the Environment (ISSE)". This model of ecosystems represents complex social ecological interactions integrating ecosystem service notion. In this paper, firstly, we will identify a list of priority ecosystem services that need to be further evaluated giving examples for each service, then we will determine the state of ecosystem services, likely the trend of evolution, drivers of change and stakeholder-related to the ecosystem service. This work is a meta paper not based on original evidence, but on existing studies.

The information collected from these two steps allows us to apply the ISSE model. This later was developed in 2007 under the US-LTER strategic research initiative “Integrative Science for Society and the Environment” (Fig. 2).

The framework questions [15] are as follow:

Q1: How do long-term press disturbances and short-term pulse disturbances interact to alter ecosystem structure and function?

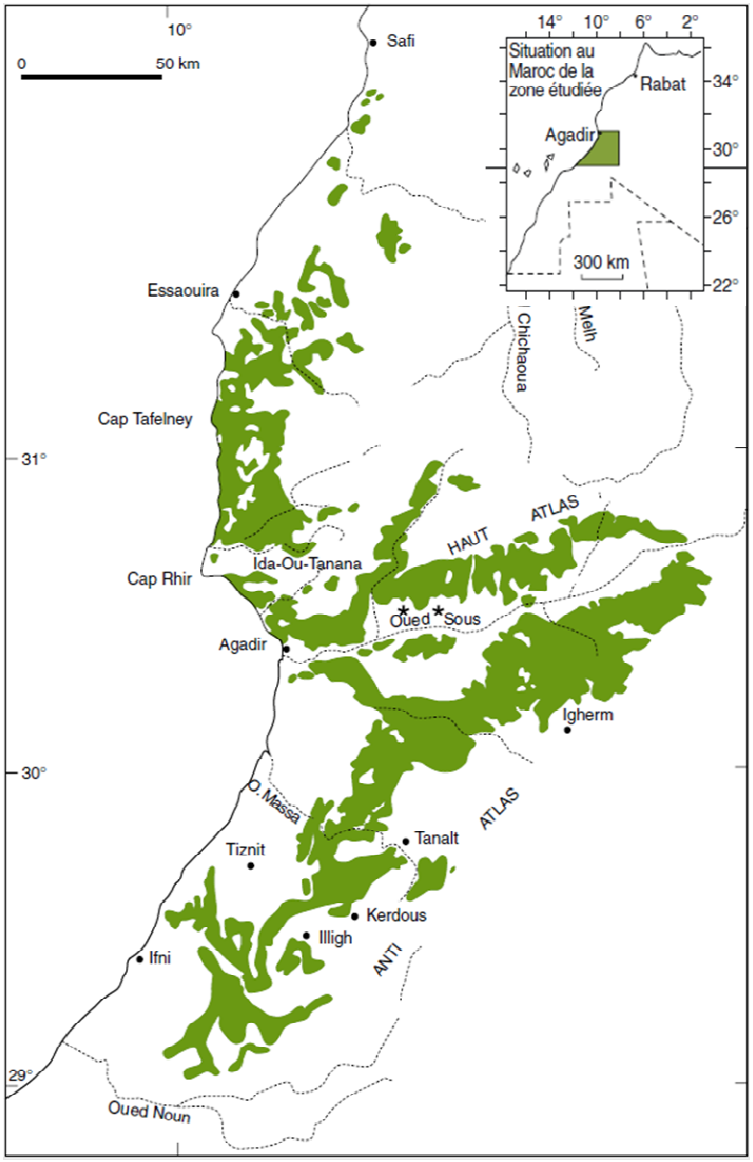

Fig. 1. Geographic location of the study area in Morocco [14]

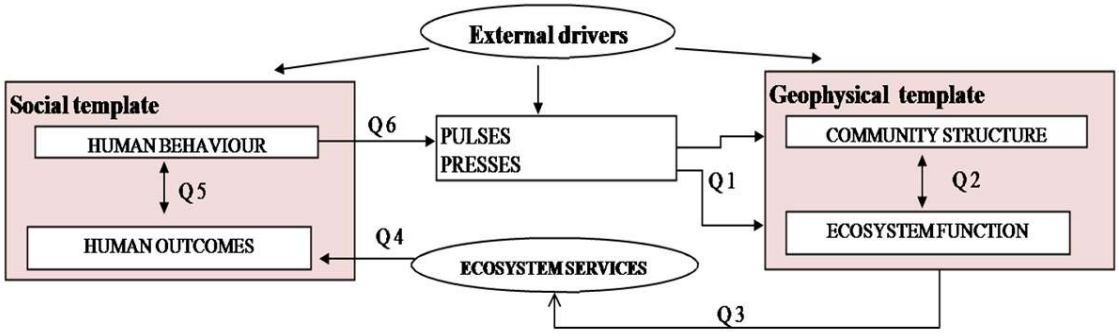

Fig. 2. Socio-ecological system [15]

Q2: How can biotic structure be both a cause and consequence of ecological fluxes of energy & matter?
Q3: How do altered ecosystem dynamics affect ecosystem services?
Q4: How do changes in vital ecosystem services alter human outcomes?
Q5: How do perceptions and outcomes affect human behavior?
Q6: Which human actions influence the frequency, magnitude, or form of press and pulse disturbance regimes across ecosystems, and what determines these human actions?

3. RESULTS

3.1 Step1: List of Priority Ecosystem Services that Need to be Further Evaluated

The information collected to date is divided into 4 groups of ecosystem services following the classification of the Millennium Ecosystem Assessment (MEA). Table 1 provides a summary of the various services offered by the argan agrosystem and related to argan ecosystem functions. Data were collected through bibliographic research.

The argan forest of south east of Morocco is located between the Atlantic coastal zone and the high Atlas Mountain; it consists of an area of about 950,000 ha. The total population of this region is 3 million people; 1.3 million people are directly dependent on the argan forest. The major urban center is Agadir. The Moroccan argan forest extends in the provinces of Essaouira, Agadir, Taroudant, Safi, and Guelmim. The argan forest offers a large number of ecosystem services and a rich biodiversity. This wealth is reflected in the existence of a number of ecosystem services such as wood, water supply, recreation, hunting landscape etc... Thereby, we identified 19 types of ecosystem services, classified into the four categories (MEA classification).

3.2 Step 2: State of Ecosystem Services, Likely Trends of Evolution

After determining and characterizing the different ecosystem services, we will conduct an assessment of the status and likely trends of the determined ecosystem services. In Table 2, each line refers to an ecosystem service, which is, in turn, associated with the site or ecosystem that generates it. The columns used to record the current status of ecosystem services and trends of changes in supply (services provided by the argan ecosystem) and demand (by population), and summarize what are the direct and indirect drivers of change and who is responsible.

Habitat for species, tourism, and conservation of genetic diversity, food, and fresh water constitute the most important ecosystem services in the argan forest. The main beneficiaries are the local population (thanks to pasturage and crops), the water users and tourists, the global community, which derives profits from carbon sequestration in forests and the existence of biodiversity.

According to previous data in this article and the information in table 4, the argan forests have undergone significant changes mainly due to human intervention. The use of the 'ISSE' Conceptual model (Integrated Science for Society and the Environment) brings together a large number of biophysical and socio-economic variables. The ISSE model considers ecosystem services as an outcome of these interactions. The argan forest is strongly influenced by population pressure (growth and land use conversion), which reduce the quality and the quantity of several ecosystem services. The status of the Moroccan argan forest mainly is related to how the man responds, or not being aware of the impact that may result from its reaction.

The Fig. 4 gathers all the argan forest elements.

4. DISCUSSION

From previous data in this paper, the argan forest is ecologically fragile, is threatened mainly by anthropogenic impacts and by climate change. In fact, this region has a long history of anthropogenic impacts such as deforestation, overgrazing as mentioned in table 2 and 3. The information assembled explores the state of the natural environment and the ecosystem services in Argan forest. The situation of environmental vulnerability is accelerated by the social vulnerability that is directly linked to argan tree services (mainly food, wood, and water). After the paper finding, the terrestrial ecosystems and associated ecosystem services is increasing:

- ✓ The use of resources such as food, water, and wood;

- ✓ The increasing deforestation decreases the argan forest capacity to regulate climate;
- ✓ Overgrazing, deforestation, and habitat destruction cause the biodiversity reduction, which affect the ability of the ecosystem to provide services;
- ✓ Increasing demand for water from a rapidly growing of population.

Table 1. List of ecosystem services of the Argan agro-forest

Ecosystem services	Examples
Provisionning services: The provisioning services including the food products derived from plants and animals; there are also fibers such as wood and genetic resources. Natural medicines and pharmaceuticals include for example food additives derived from this ecosystem.	
Food	Crops: Argan trees, cereals… Livestock: Goats, ovine, cattle, milk, honey
Fiber	Wood: Construction, firewood, decorating tools, and cordage…
Biofuel	Firewood and charcoal
Freshwater	Drinking, cleaning and washing, irrigation, power generation
Genetic resources	Local varieties and varieties resistant to pests
biochemical substance	Aromatic and medicinal plants
Regulating services: The regulating services control certain environmental parameters such as flow streams or quality of air and water. In fact, the vegetation supporting salinity provides a suitable habitat for many insects and birds. The vegetation cover as a whole regulates water quality through a variety of biological processes. The edges of the Wadis are particularly important habitats, through the provision of nutrients and mud that covers their depths. This mud provides food and suitable habitat for small animals. The vegetation cover has an important role in the retention of the soil and prevents landslides.	
Air quality and the climate	Argan groves, Fires, and lakes…
Carbon sequestration	Argan groves (Storage of CO2), livestock emit methane. local rainfall
Attenuation of extreme events	Potential water storage in the ecosystem The Argan groves retain water minimizing the magnitude of flooding
Wastewater Treatment	Trapping heavy metals, microbial soil degrades organic waste, making them less toxic. Agrosystems and forest minimize the occurrence of stagnant water
Preventing erosion	Argan groves plays the windbreaks prevent siltation of Argan Wadis
Biological Control	Bats, toads and snakes feed on pests that attack crops
Pollination	Beekeeping (pollination of crops)
Cultural services: The cultural services obtained from ecosystems through spiritual enrichment, reflection, and recreation, including cultural diversity. Tourism in the region is developing; it is supported by the government. The argan forest provides a rich source of inspiration for education, art, folklore (local dance and music), and national symbols. Aesthetic values lead many people to find beauty in various aspects of ecosystems.	
Recreation & ecotourism	Hiking, camping, Bivouac
Ethical values	Mousemes , Souks, Zaouias, spiritual, religious, and aesthetic values
Supporting services: The supporting services are the origin elements for the production of several other ecosystem services (soil formation and primary production, etc.). The phenomenon of photosynthesis for example allows plants to capture carbon dioxide (CO2) and release oxygen (O2). The vegetation is very essential in regulating siltation and siltation of streams. In fact, people have changed considerably almost all components of the argan forest, by conversion of forests to cropland, urbanization (reference). Indeed, these human interventions have disrupted the argan tree functions.	
Habitat for species	Decomposition of organic matter contributes to soil fertility
Genetic diversity	Photosynthesis and nutrient uptake

Table 2. State of ecosystem services, likely trends of evolution, drivers of change and stakeholder-related factor

Ecosystem Services	Site or habitat that generates service	Current state of the ecosystem service ++ very good, + good, -Poor - -very poor	Probable future trends (increasing ⇧, stable ⇨, decreasing ⇩)		Drivers of change	Stakeholders and actions related to the Drivers of change
			Demand	Supply		
Provisionning services						
Food	Argan groves	-	⇧	⇩	Overgrazing Deforestation	HCEFLCD ORMVA Farmers
Fiber	Argan groves	-	⇧	⇩	Drought	HCEFLCD Farmers
Biofuel	Mountains Agrosystem	+/-	⇨	⇨	-	HCEFLCD NGOs
Freshwater	Wadis/groundwater	+/-	⇧	⇩	Human overuse	ONEE, ABH NGOs
Genetic resources	Argan forest	-	⇨	⇨	-	HCEFLCD
biochemical substance	Argan forest	-	⇧	⇩	Human overuse	Herbalists Pharmaceutical industry
Regulating services						
Air quality and the climate	Forests Agrosystems	-/--	⇧	⇩	-	HCEFLCD NGOs, farmers smallholders
Carbon sequestration	Catchment	-/--	⇧	⇩	Deforestation	HCEFLCD ABH NGOs
Attenuation of extreme events	Forests Agrosystem	-	⇧	⇩	-	HCEFLCD ORMVA & NGOs
Wastewater Treatment	Wetlands Agrosystem	+/-	⇧	⇩	-	HCEFLCD ORMVA
Preventing erosion	Catchment	-/--	⇧	⇩	Drought	HCEFLCD

Ecosystem Services	Site or habitat that generates service	Current state of the ecosystem service ++ very good, + good,	Probable future trends (increasing ⇧, stable ⇨, decreasing ⇩		Drivers of change	Stakeholders and actions related to the
Biological Control	Catchment	-/--	⇧	⇩	Drought Overuse and pollution	HCEFLCD NGOs
Pollination	Agrosystem	-	⇧	⇨	Overgrazing Deforestation	NGOs Smallholders
Supporting services						
Habitat for species	Agrosystem	-	⇧	⇩	Salinization	HCEFLCD
Conservation of genetic diversity	Agrosystem	-	⇧	⇩	Drought	HCEFLCD
Cultural services						
Recreation & ecotourism	Agrosystem Forest Mountain	+/-	⇧	⇨	Deforestation	Tourism Sector NGOs Smallholders
Ethical values	Catchment and Groundwater	-/--	⇧	⇩	Drought Overuse	ONEE, ABH HCEFLC private sector

Were ORMVA: Office Régional de Mise en Valeur Agricole ; HCEFLCD: Haut Commissariat des Eaux et Foret et Lutte contre la Désertification.

Table 4. ISSE model indicators and components of the argan forest area

Component	Indicator	State	Reference
Community structure and Ecosystem function	Argan trees area	Forest decline in the argan woodlands results from a combination of lack of regrowth and loss of trees	[16]
		During the period 1969- 1986, the Argan plain lost an average of 550 ha/year.	[17]
		In Haha zone (western High Atlas), the de-densification is of the order of 600 ha/year.	[18]
	Cereals	Argan forests have been exploited as a shade tree for cereal crops, thereby, supporting the local economy	[19]
	Fiber	The Arganeraie have been exploited as firewood, timber, as forage for goats and sheep.	[19]
	Biodiversity	Actually argan forest continues to be destroyed with all its components of biodiversity.	[7]
	Animal	The development and valorization of production of goats reared in Arganeraie depends on the	[20]

Component	Indicator	State	Reference
	production	self awareness of goat farmers and consumers, and the commitment of decision makers	
	Supply/demand	Agricultural development in these forest plains remains linked to the exploitation of surface water.	[21]
Pulses & presses	Aridity	Increasing aridity, at a regional-scale	[22]
		In argan forest, aridity was considered to increase developmental instability, and decreasing resilience.	[19]
	Overgrazing	Rangelands in plots exclosure areas are one of the main violations.	[23]
		Enclosure experiments in two areas showed that re-growth does occur if grazing is excluded.	[24]; [39]
	Wood extraction	In the arganeraie, the cuts of wood are one of the leading contraventions.	[23]
		Caused partly by overgrazing, as animals eat new saplings.	[25]
		Overgrazing may also damage soils, remove understory and cause erosion.	[26]; [11]; [16]
	Drought	During drought years the amount of surface water may drop 20 times.	[27]
		Excessive water stress during long and severe droughts may increase mortality in tree stands, especially those on slopes and with high sun exposure.	[28]
		Droughts may exacerbate grazing pressures on existing resources.	[11]
	Soil erosion	Clearing of trees causes erosion that, along with soil degradation (in the form of salinization and loss of organic matter, mostly in irrigated areas), may render some soils unfavorable for germination.	[29]
	Salinisation	The over-pumping that can induce saltwater intrusion problems.	[21]
	Pesticides	There are only some Argan trees scattered in areas that are polluted by pesticides.	[30]
Human behavior (Social template)	Clearing	The gradual extension of cultures has led to repeated clearings mainly in the plains.	[21]
		Clearings stands for expansion of agricultural land caused a loss surface of about 19.4%.	[23]
	Irrigation	Irrigation reinforces accelerate clearing and imbalances.	[21]
	Groundwater	The groundwater in Souss Massa show an average drawdown of 1 to 2m/ year.	[21]
	Urbanization	Agadir- Ait Melloul urban centers, as well as smaller centers, have been expanding into the argan forest.	[31]
	Dams	In Souss-Massa the amount of water surface available exceeds 600 million m^3 stored in the Abdelmoumen dams in Aouloz and Youssef Ben Tachfine Dam.	[21]
	Legislation	Agrarian operating modes of the argan tree are changing rapidly and the legislation does not follow the same rhythm.	[11]
	Soil fixation	Argan tree ecosystem plays an important role in the fight against desertification and erosion.	[32]
	Reserves	The UNESCO and the Moroccan State classified the Moroccan argan tree as Biosphere Reserve in 1998.	[33]
Human outcomes	Regeneration of argan tree	Regeneration programs initiated since 2000, but have not yielded the expected results.	[7]

Component	Indicator	State	Reference
(Social template)	Migration	A strong rural migration to the cities. 3/4 of population growth in rural areas are transferred to the cities.	[23]
	Right to use	The rights to use argan products belong only to the tribes and traditional users and concern: wood, fruit picking, pasture, land use and extraction of soil, sand and stone.	[21]
	Demography	Population growth and overgrazing caused that product demand and pressure on the forest increased	[21]
		The rural population of the Essaouira province has a negative annual growth rate (- 0.02%) in 1994- 2004.	[34]
	Tourism	Most of the accommodation is concentrated on the coastal part that has a peak attendance during the summer. (in guesthouses). Some are listed and classified but many in the informal sector.	[35]
	Cooperatives	Lybbert *et al.* (2011) noted throughout the southwest Morocco, an explosion of cooperatives between 1999 and 2007 (over one hundred cooperatives framing over 4,000 women).	[36]
	Oil price	Increasing prices for argan oil have probably led to an intensification of fruit collection since the 1990's.	[37]

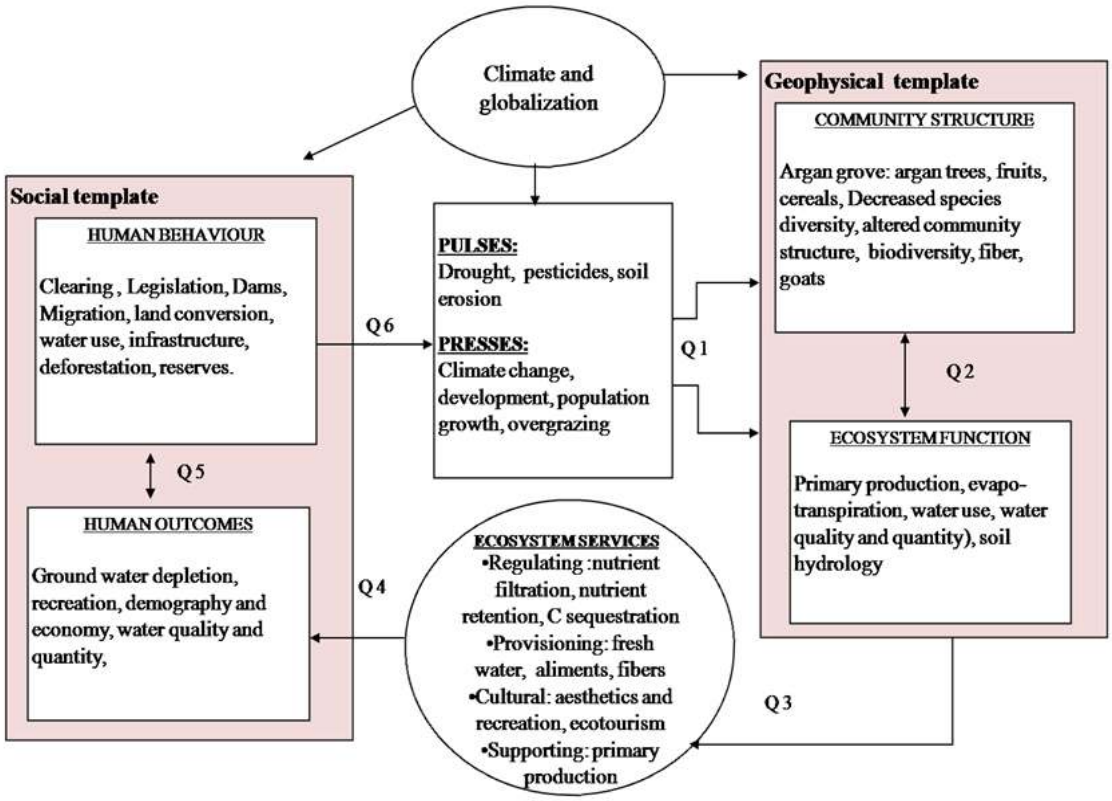

Fig. 4. Socio-ecological system of Moroccan Argan forest

The occupation and distribution of tree change faster via disturbance. The climate change can be an important cause of degradation. Admittedly, climate is projected to become unfavorable. Undoubtedly, this trend will cause the fact that the argan tree may be outside the current climatically suitable range, as a result the biomass and all associated ecosystem services will greatly increase, leading to changes in ecosystem structure and function. Several authors stated that the anthropogenic pressure is expected to have rapid effects on the structure and function of the argan forest ecosystems [31,6,8,23]. This exploitation appears having a positive impact in the short term but, on long term, it will cause significant economic and social impacts. Changes in forest ecosystems that affect argan forest can be assessed using tools of vulnerability assessment (use of the EVI or Environmental Vulnerability Index at regional scale). A successful adaptation must be based on work collaboratively within public agencies and local stakeholders. The Mediterranean products have specific and interesting qualities but still need to be better valorized [20]. Basing on the previous outputs, mitigation and adaptation measures are therefore needed. Any environmental protection should started at first by the improving the living conditions of the population that derives its income mainly from argan forest. His survival behavior threatens this heritage for a long time to meet human needs. However, the changing of the farming practices can encourage and move towards ecotourism that could contribute to the protection of the argan ecosystems.

The education on sustainable action and climate change impact is a good starting point who may want to begin the adaptation process. The ISSE framework adapted for the argan forest can allows managing the ecosystem services in the context of climate change, and will give a large range of options for managing of this endemic heritage.

5. CONCLUSION

In future, forest ecosystem services in Morocco will differ from those of today as a result of

anthropogenic impact and changing climate. Although increases in temperature, changes in precipitation may change ecosystem structure and function.

The argan forest offers a rich biodiversity that supports a large number of ecosystem services. Now, it is threatened, the environmental vulnerability is much greater in this region, which is at the head of the most threatened forest of Morocco. Managers and decisions-makers need models that show how human act on natural systems [38]. The 'ISSE' conceptual model can be used to understand how humans perceive the services provided by ecosystems, how these perceptions change behavior, and how these changes in turn feed back to affect ecosystem structure and function, passing through the listing of different ecosystem services and their actual and trends state.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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