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Article

Anthropogenic Decline of Ecosystem Services Threatens the Integrity of the Unique Hyrcanian (Caspian) Forests in Northern Iran

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Abstract: The unique Hyrcanian (Caspian) forests of northern Iran provide vital ecosystem services for local and global communities. We assess the status and trends of key ecosystem services in this region where native forest conversion has accelerated to make way for housing and farm development. This is a mountainous forested area that is valuable for both conservation and multiple human uses including recreation and farming. It contains globally significant natural habitats for *in situ* conservation of biological diversity. A rapid, qualitative, and participatory approach was used including interviews with local households and experts in combination with assessment of land use/cover remote sensing data to identify and map priority ecosystem services in the Geographic Information System (GIS). Based on the interests of the beneficiaries, eight priority services (food production, water supply, raw materials, soil conservation, water regulation, climate regulation, biodiversity, and recreation) were identified and mapped. The results indicate the current typical spatial distribution of the provided services based on structural characteristics of the study landscape and their changing trends through a comparison of past, present and future land use, and land cover. Although food production and recreation have greatly increased in recent decades, the other services, in particular timber production, biodiversity, and water purification and supply are being gradually lost. The results of this study and of others elsewhere should raise awareness of ecosystem service status and trends and the value of examining these since they provide much of the information to inform natural resources policy and decision making. The declines in supply of key ecosystem services both within and outside the protected area are creating conflicts within communities as well as impacting on the integrity of the area and careful planning and conservation is required to provide win-win opportunities.

Keywords: Ecosystem services; land cover; household survey; value judgment; rapid Assessment: participatory approaches; GIS

1. Introduction

Forested ecosystems provide a wide range of benefits to people and the vulnerability of these benefits to anthropogenic change has become the focus of intense research and policy interest [1–7]. The development of new approaches to assess ecosystem services (ES) has led to different definitions of these services by various authors [8–13]. However, the most common and widely accepted definition provided by the Millennium Ecosystem Assessment (MEA) [4], defines ES as "the benefits people obtain from ecosystems". These benefits include provisioning, regulating, and cultural services that directly affect people and the supporting services needed to maintain other services. Application of this approach may provide both the protection of ES and economic development and suggest indicators and metrics which can be used for effective policy design and increased likelihood of win–win outcomes [14–16].

Ecosystem services assessments at landscape level are important because they contain many important functions which provide numerous ES to society [17–19]. Assessment of ES at the landscape scale helps effectively integrate the concept into land management decisions [14,20,21]. Forested landscapes tend to provide a high diversity and high quality of ES since they usually contain large amounts of natural vegetation. In general, they reduce the energy from wind and water, increase water filtration, conserve soil, support natural habitats for a rich biota of terrestrial and aquatic species, and resist the establishment of invasive species. However, many forested landscapes are changing rapidly in response to changes in key social and ecological drivers such as land use change and global warming [22–24].

Undertaking an assessment of ES adds value to decision making helping (i) to determine and communicate the broader ramifications of decisions, policies, and planned schemes, (ii) the consideration of options for the future use or management of habitats, (iii) to broaden the scope of impact assessments, (iv) to address the robustness of business plans, and v) to communicate with and better engage local communities [25,26]. Rapid assessment methods hold a central position in environmental monitoring programs because once established, they can provide sound, quantitative information on the status of the natural resources with a relatively small investment of time and effort [26,27] and have been shown to be sensitive to anthropogenic impacts on natural ecosystems [28–31]. As shown in Table A1, a number of forested landscapes throughout the world have been recognized as globally significant through their listing as world heritage sites. These forests meet one or more of a number of strict natural criteria including: i) to contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance according to the United Nations Educational, Scientific, and Cultural Organization (UNESCO) criterion; ii) to be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features; iii) to be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal, and marine ecosystems and communities of plants and animals; and (iv) to contain the most important and significant natural habitats for *in situ* conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation. Some of these sites also meet one or more of these criteria. In spite of their immense natural significance there have been limited studies of the ES of these world heritage areas and how these may be changing due to anthropogenic forces (Table A1). Here we examine ES in a unique forest landscape that Iran tentatively listed in 2007 for World Heritage nomination, the Hyrcanian (Caspian) forests in the north of the country close to the Caspian Sea. Iran has listed a large number of potential World Heritage sites for submission to UNESCO for consideration but only a few are natural sites.

In Iran, as in many developing countries and despite several decades of environmental protection and progress in conducting environmental impact assessments (EIA) and land suitability evaluation, the ES concept has not yet been adopted by planners and managers. One reason for this delay in uptake is the dominance of the sector specific approach in the planning system, which often overlooks integrated planning approaches such as ES. In addition, application of the ES concept in Iran has remained in its infancy due to the lack of expertise and quantified data, especially with regards to measuring and regulating ES, which requires appropriate techniques and modeling tools because of their inherently complex nature. This research is the first practical step in the application of ES assessment at the local level scale in forested landscape and protected areas of the Sarvelat and Javaherdasht district in northern Iran, where native forest land conversion has accelerated for housing and farm development. This area is valuable for both conservation and multiple human uses including recreation and farming. Despite its global significance, in recent decades this area has been under pressure from both direct and indirect drivers of change which are gradually altering natural habitats.

Since the establishment of a protected area in the southern part of the landscape and given that this area is bordered in the north by the Caspian Sea, there is only a limited area of flat plains suitable for cultivation and construction. In recent years the growing demand for the development of land for farming and housing has resulted in accelerated forest cover conversion at increasingly higher elevations and close to the protected areas. These changes have resulted in increased conflicts among various stakeholders including local residents, environmental organizations, and construction companies. Land use changes are occurring in the absence of spatial assessments of ES so clear links between such services and the spatial representation of functioning ecosystems or natural vegetation remnants are lacking. Therefore, there is a pressing need for readily available information and spatial assessment of ES for planners and managers to use to guide, or at least inform, decision making around ES and biodiversity issues.

Our specific aims were (a) to identify the priority ES in the study area, (b) to examine the relationships between land uses and ES provision, (c) to map the spatial distribution of priority ES, (d) to assess ES trends over time, (e) to understand the impacts of actual and potential changes in land covers on ES, and (f) to provide useful information for both conservation and development decision making.

2. Methodology

2.1. Study Area

The Hyrcanian (Caspian) forest of northern Iran and southern Azerbaijan is a deciduous broad-leaved forest which has been labeled a Global 200 Ecoregion by the World Wide Fund for Nature (WWF). It contains remnants from the Tertiary period and is rich in relic and endemic species (around 150 endemic species of trees and shrubs, up to 60 mammal species, plus 340 birds, 67 fish, 29 reptile, and nine amphibian species). The landscape lies along an important migratory route between Russia and Africa and is listed as an important bird area (IBA) [32]. It has been listed by Iran as tentative for nomination as a World heritage site in the future [33]. Our study area comprises the Sarvelat and Javaherdasht districts which occupy an area of 55,829 hectares, located between 37°03′ N–36°48′ S of latitude and 50°22′–50°45′ E of longitude. This area is administratively situated within the boundaries of two provinces, Gilan and Mazandaran, in the northern part of Iran (Figure 1). Iran declared 21,254 hectares of this as a protected area in 1999. It is mountainous with many rivers and an elevation range of zero–3550 meters above sea level. The average annual temperature in the lowlands is 14 °C and with a precipitation of 1150 mm which gives it a humid temperate climate. The presence of ancient Hyrcanian forests composed of semi-dense to dense forest in the uplands and low density forest at lower elevations are considered to be the main features of this area.

Socio-economically two important adjacent urban areas are Ramsar in the Southeast and Chboksar in the southern parts of the study area, with populations of 102,481 and 25,301, respectively. Of the 180 villages within the study area 36 do not have permanent populations and are used as summer villages. The remnant 144 villages range from 10 to more than 2000 people each. The majority of local people are farmers. In addition, due to the unique natural attractions of the area, many of these farmers are also active in providing different services for tourists including accommodation, tourist trips, and catering/hospitality services.

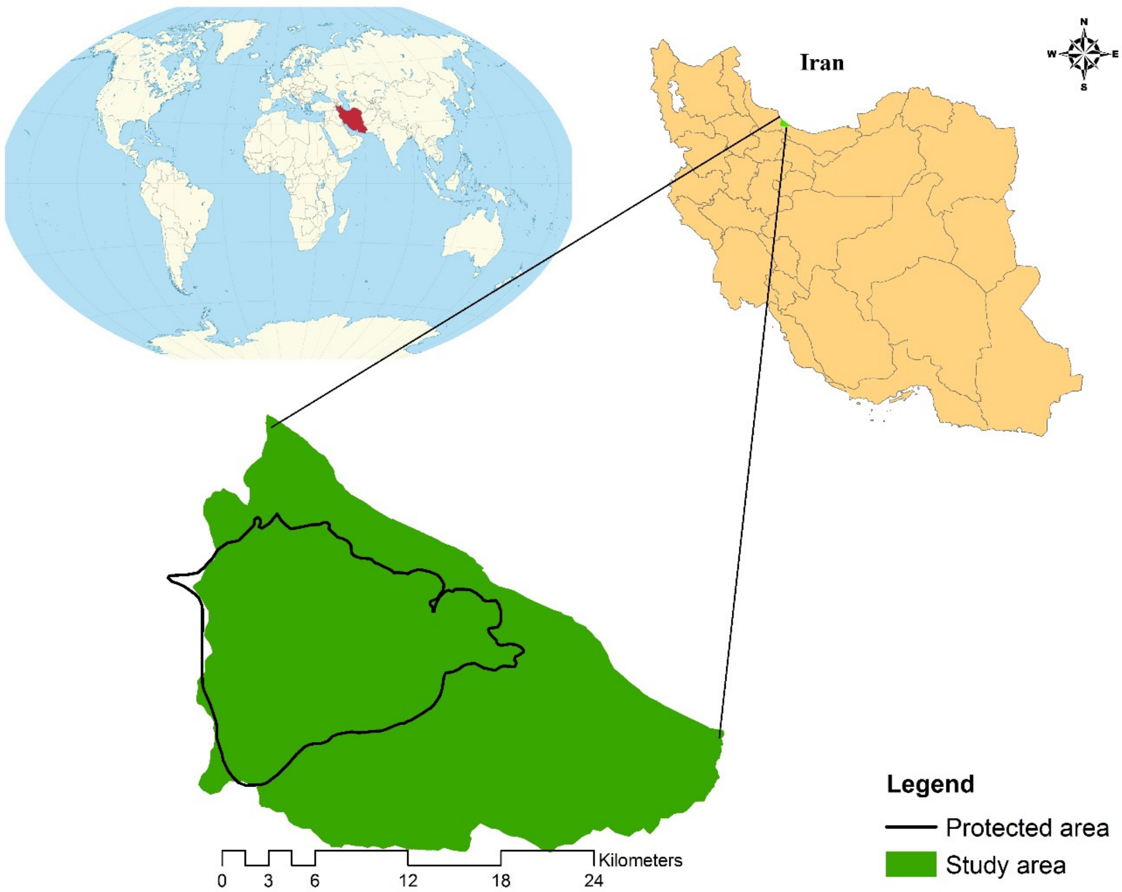


Figure 1. Geographic location of the Sarvelat and Javaherdasht district and the World Heritage Hyrcanian (Caspian) forests area.

2.2. Study Approach and Design

Although there are a variety of ways to assess ES and examine changes in these over time, financial restrictions, limited time, and lack of quantified data for conducting this study led us to apply a simple, rapid, and qualitative assessment approach [23,34]. The approach taken attempts to determine the potential capacity of a given landscape to provide a group of ES [35–37]. Several approaches were used including participatory mapping, expert views or professional judgment, and questionnaires and surveys [38–40]. At first, we assessed the changes in land use/ land cover (LULC) of the study landscape using past LULC (2000), present LULC (2013), and a hypothetical future LULC (2030), because there is evidence that emphasizes the linkages between LULC and ES provision [35,41,42]. We worked with both local community and academic experts to determine the potential capacity of the study landscape to provide a bundle of ES. To identify the most important ES at the landscape in its current state, we carried out a random household survey through direct interviews with local people who benefit from ES.

We also used a simple assessment method to relate the selected priority ES to different classes of the current LULC map based on expert judgment in cooperation with academics. After analyzing the questionnaire responses, and by calculating the average valuation that specialists applied to each land cover type in terms of their capacity for providing different ES, the results were transferred to GIS Arc Map 9.3 software. Different ES maps were produced as spatially-expressed information on local use and expert perceptions of ES across the study area. Figure 2 presents the approach taken in the study area in order to conduct a qualitative rapid assessment of ES.

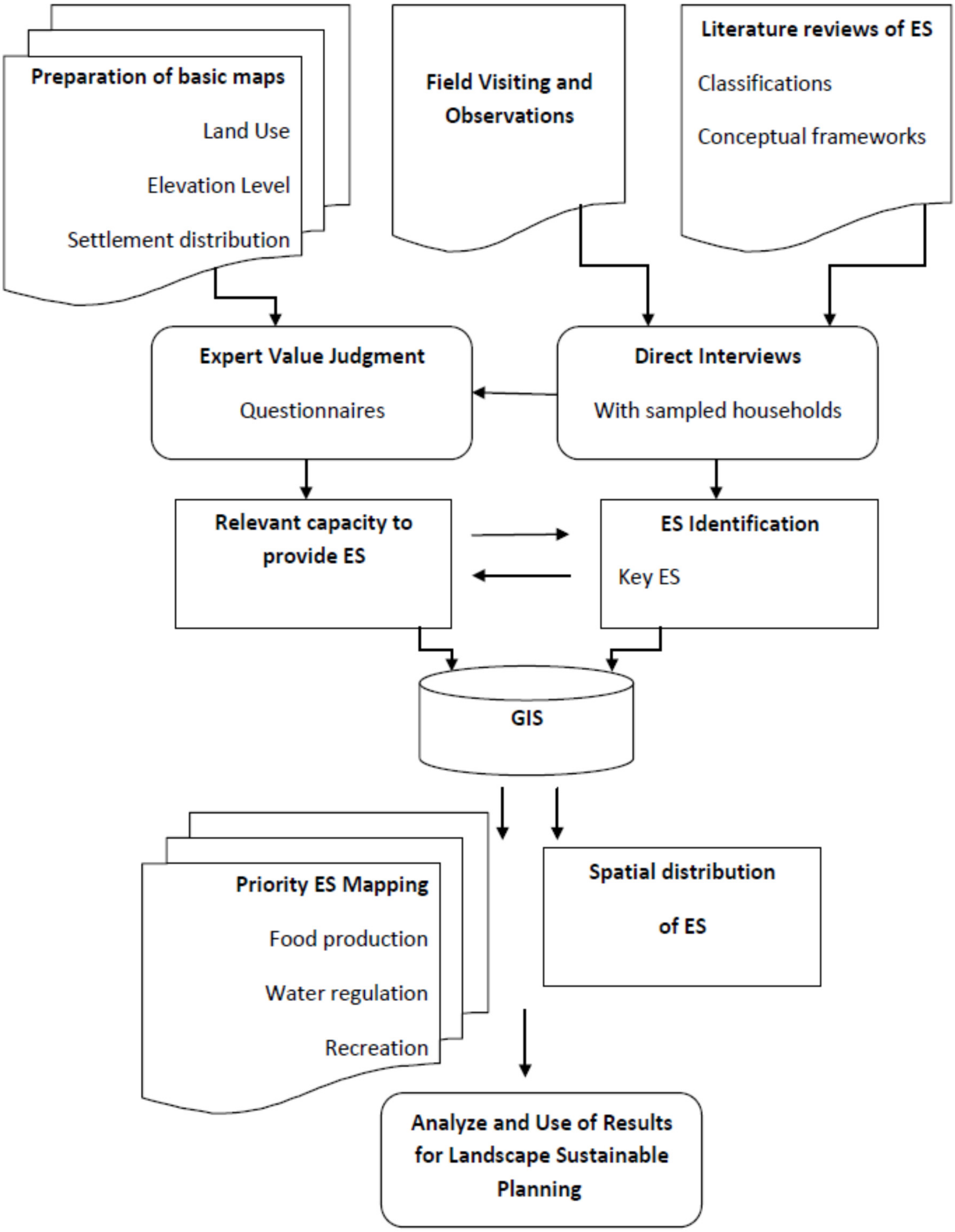


Figure 2. Practical approach of qualitative rapid assessment of Ecosystem Services (ES) in the study area.

2.2.1. Mapping of the LULC Changes based on Past, Present, and Plausible Future LU Changes

To produce past and present LULC maps we used two Landsat images of the sensors Enhanced Thematic Mapper (ETM) and The Operational Land Imager (OLI) (path163/row34) for the years 2000 and 2013, respectively. The satellite images were downloaded from the Global Land Cover Facility (GLCF) (http://glcf.umd.edu/) and U.S. Geological Survey (USGS) (http://www.usgs.gov/). The past LULC layer presents the baseline condition of the study landscape (Figure 3a). For the present

LULC map after geometric correction, we performed ground truthing to validate the map based on the current situation of the study landscape. This map depicts the changes that have occurred during 2000-2013 (Figure 3b). We also generated a plausible future LULC map using recent past changes in landscape. As ES assessment is a support tool for informed decision making, this map can reveal the difference between the amounts of the ecosystem service(s) provided by the current landscape compared to a plausible future, when natural forest habitats will be converted to anthropogenic land uses. Based on a comparison between the past and present LULC, farmland development and housing were considered as the key drivers of changes in natural forest cover. Here we reclassified all low-density forest cover remnants in the present land cover at an elevation of up to 400 m as farmlands, and some parts of semi-dense forest cover at elevations up to 1800 m that were not in protected areas as human settlements. (Figure 3c).

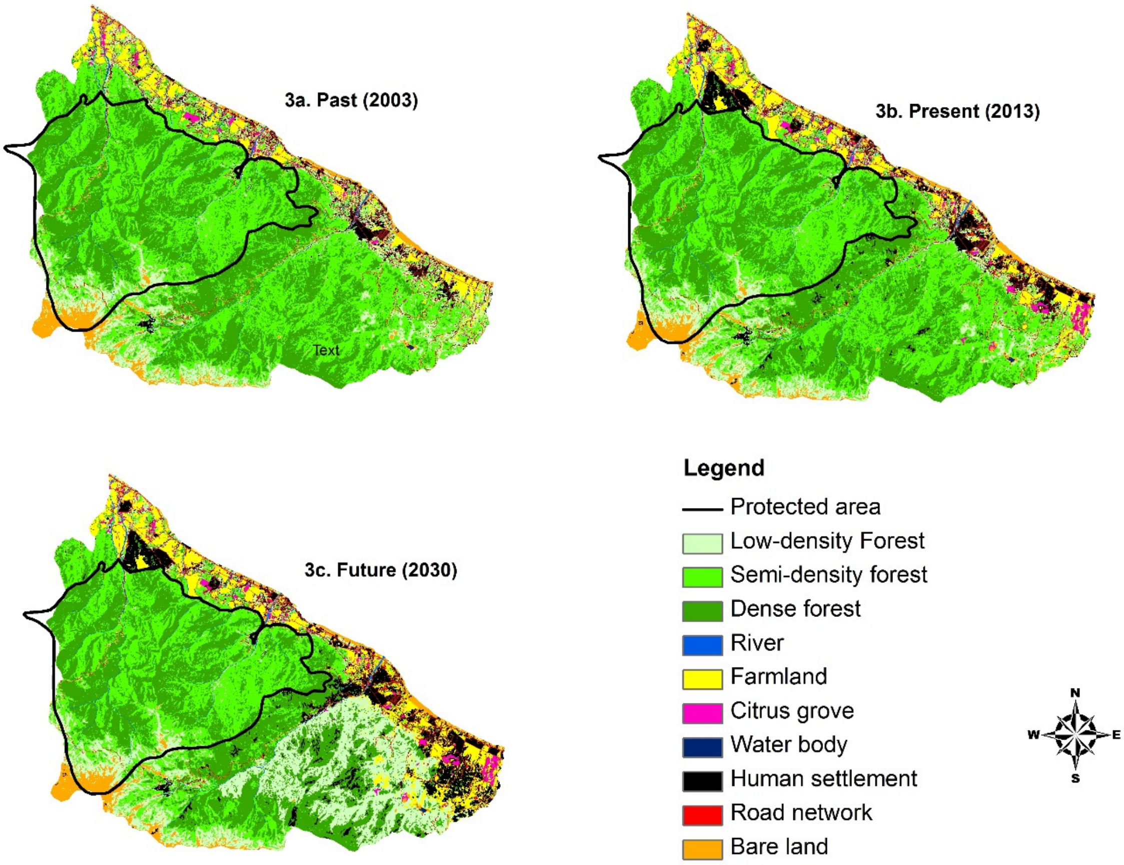


Figure 3. Past land use/land cover (LULC) (**a**); present, LULC (**b**); and plausible future LULC, if the current situation of LULC change continues (**c**) for the Sarvelat and Javaherdasht district.

Identifying the area occupied by each LULC class at a landscape can guide us in assessing and quantifying the ecosystem services delivered at that landscape [41]. Therefore, as shown in Table 1, we classified the existing habitat and non habitat classes for all three above-mentioned LULC maps to compare the area and the percentage cover of each of the land cover classes under past, present, and plausible future scenarios.

Table 1. The area (ha) of each LULC classes under past, present, and plausible future situation.

LULC Class	Past LULC Area	Present LULC Area	Plausible Future LULC Area
Low-density forest	3620	5507	10139
Semi-density forest	19384	21730	14528
Dense forest	25369	18442	18358
River	437	437	432
Farmlands	1753	2892	4147
Citrus	232	614	609
Water body	1	13	13
Settlement	1112	2559	4000
Road network	1849	1424	1425
Bare land	2072	2211	2178

2.2.2. Sample Selection

To determine the number of households for a household survey an appropriate sample size was needed to provide an acceptable level of precision. As this study had limited resources and since the human population of our landscape was relatively homogenous, we accepted a margin of error of 10% (5% is a common choice). The total number of households in the study landscape was 6762. Therefore, after determination of the mean (37) and the standard deviation (73) of the 6762 households, the number of sample size calculated equal with 95 with a confidence level to 95% using the Raosoft sample size calculator (http://www.raosoft.com/samplesize.html). To select the villages in which the direct interviews were carried out, we only considered 144 villages that have permanent populations (Figure 4). Then after considering other factors including the number of households in each village, their respective distances from the boundary of the protected area, and their geographical distribution across the landscape, 17 villages were selected which have been listed with more detail in Table 2.

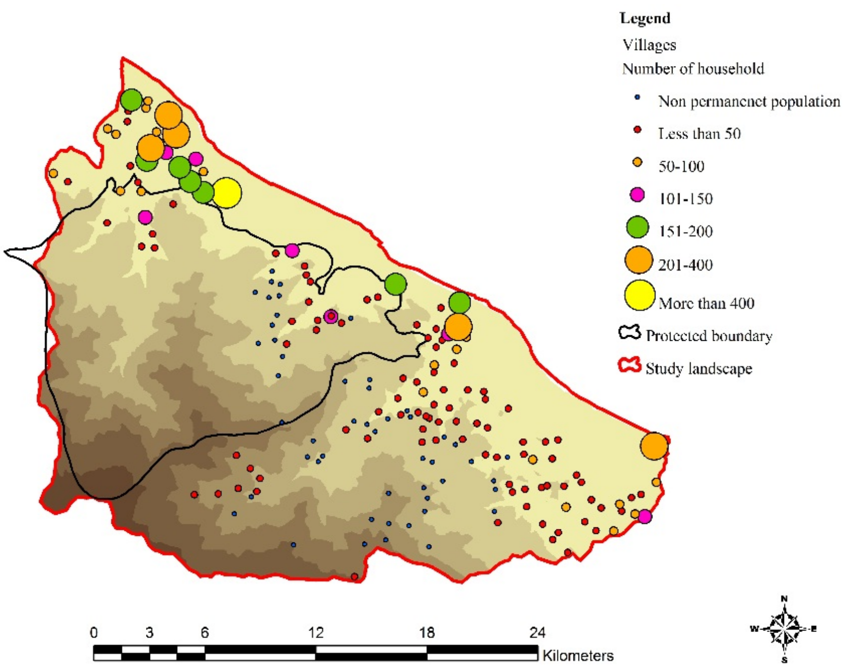


Figure 4. Classification of study villages based on their population, number of households, and geographical distribution across the study landscape.

Table 2. Villages selected for direct interviews based on a range of criteria including population size, number of households, and geographical location.

Name of villages	Number of households	Number of households were interviewed	Population	Elevation level (m/asl)	Approximate distance to protected area (m)
Ghasem Abad Sofla	634	20	2631	−27–400	1066
Chayjan	329	8	1286	−27–400	2900
Kelayeh Bon	246	8	1025	−27–400	13900
Talesh Mahaleh	226	8	937	−27–400	1884
Syahkalroud	211	8	839	−27–400	2463
Darya Poshteh	189	5		−27–400	2575
Sefid Tameshk	154	5	646	−27–400	Inside
Jangsara	103	5	444	400–1000	Inside
Sajidan	101	5	486	−27–400	Inside
Mian lat	93	3	404	−27–400	2250
Shad Morad Mahaleh	76	3	303	−27–400	14700
Gilamolk	58	3	270	−27–400	2935
Disar	57	3	227	−27–400	1000
Salmal	5	2	17	1800–2200	Inside
Limeh sara	48	3	239	400–900	Inside
Javaher Deh	27	3	71	2200–2800	2657
Vach kelayeh	36	3	168	400–900	1000

2.2.3. Household Survey through Direct Interviews

To conduct the household survey two local experts were recruited during the months of March and April 2014 to assist in collecting data through completing questionnaires. Households were interviewed to determine what householders considered to be the most important ES for the studied landscape. We used a questionnaire table which was adopted from the Toolkit for Ecosystem Service Site-based Assessment (TESSA) [41], as shown in Table A2. Since ES is not a commonly recognizable concept, each interviewee was briefly introduced to a simple definition and types of ES. Then we asked the local interviewees to give an opinion about: (i) the existence or lack of each type of benefit that is delivered by the study landscape; and (ii) the existence or lack of each type of ES and score all the benefits from 0–5 on a scale consisting of: 0 = not relevant; 1 = of low importance; 5 = highly important. During the interviews we described to them the importance of benefits, taking into account both the number of people benefitting and the contribution of the benefit to different values including economic (the ability to earn an income and to have assets), human (health, education, nutrition, clean water, and shelter), socio-cultural (sense of place, spiritual wellbeing, recreation), and protective (ability to withstand economic and external shocks). The highest scoring benefits were selected as priority ES provided by the landscape.

We also used Table A3 as a more detailed questionnaire table to discover trends in changes of priority ES during the recent decade. Each respondent was asked to specify the benefit availability during the recent 10 years as: increased, stable, or decreased. Their dependencies to the benefits were specified using relative values of very high, moderate, and low. They also were asked to suggest the driver of changes to individual ES.

2.2.4. Determination of the Relevant Capacity of LULC Classes to Provide ES Based on Expert Judgment

To determine the current level of ES delivery generated by each LULC type, we worked with a group of 20 scientists from different sectors including associated governmental institutions (e.g., Department of Environmental Protection, Forestry, and Rangeland Organization, Ministry of Water, and academic and research centers. Six of these scientists were also members of the Iranian Association for Environmental Assessment (http://www.iraneia.ir/en) with relevant experience associated with ecosystem assessment. First, we asked them to specify the relationship or disaffiliation between each LULC class and different types of ES by ticking Y (for yes) and N (for no) in a matrix which has shown in Table A4 [38] in order to characterize the ES generating resources. Then the related ES were scored by them between 0–5 on a scale consisting of: 0 = not applicable of the particular land cover type to supply selected ES, 1 = very low capacity, 2 = low capacity, 3 = medium capacity, 4 = high capacity, and 5 = very high capacity. Scores were then averaged, and are presented in Table 3.

Table 3. Ecosystem services scored for different land use classes based on expert judgment. Scores were rated on a scale from 0–5 where 0 represented no service and 5 the maximum potential service.

Ecosystem Service	Low-density forest	Medium density forest	Dense forest	River	Farmland	Citrus groves	Water body	Settlement	Road network	Bare land
Food provision	1.2	1.80	2.68	3.62	5	4.18	3.75	0	0.8	0.53
Raw materials	3.75	4	5	2.87	3.25	2.5	2.62	0	0.8	1.13
Water supply	2.80	3.20	4.53	4.56	1.6	2.2	4.43	0	0	0.8
Soil conservation	3.9	4.5	5	2.2	2.18	3.9	3.06	0	0	0.66
Water regulation	4.18	4.8	5	4.31	2.5	3.2	4.62	0	0	0.86
Climate regulation	3.5	4.33	5	3.5	2.75	3	3.68	0	0	0.73
Biodiversity	4.62	5	5	4.18	2.43	3.62	4.5	1.12	0	0.8
Recreation	5	5	5	4.68	2.18	4.43	4.93	3.06	2.9	1.4

The average capacity values were then transferred to GIS Arc Map software to produce eight maps for eight key ES and present their relative values of provision in a spatial-temporal manner for potential, actual, and plausible scenarios for the study landscape.

3. Results

3.1. Priority ES in Sarvelat and Javaherdasht District Forests

The household survey showed that the landscape provided a wide range of ES but eight scored as the most important benefits (Table 4). These were from all four categories described by MA [4]: two were in provisioning services (food, raw materials, and fresh water), three in regulating services (soil conservation, water regulation, and climate regulation), one supporting service (biodiversity), and one cultural service (recreation). Some types of ES were also of different sub-categories as shown in Table 4. This survey also indicated that local people put more value on provisioning services that have major impacts on their subsistence. As this result could be different from the opinion of the experts who made judgments about the capacity of LULC classes to provide ES, we held a consensus-based session with the participation of some selected representatives from both sides in order to rank a final list of top priority ES. This session resulted in the identification of eight ES as top priorities. These were: water supply, food production, recreation, soil conservation, water regulation, biodiversity, climate regulation, and raw materials. With respect to trends in changes of ES availability suggested by local communities, while some provisioning services such as rice, citrus, and forage are related to anthropogenic LULC expansion in the last decade, some other provisioning services such as fish stock, honey provision, timber production, as well as most of the regulating and supporting services are decreasing as they are dependent on intact natural LULC. Recreation as a cultural service is continuously increasing because of an increasing number of visitors who now have improved road access and transportation facilities.

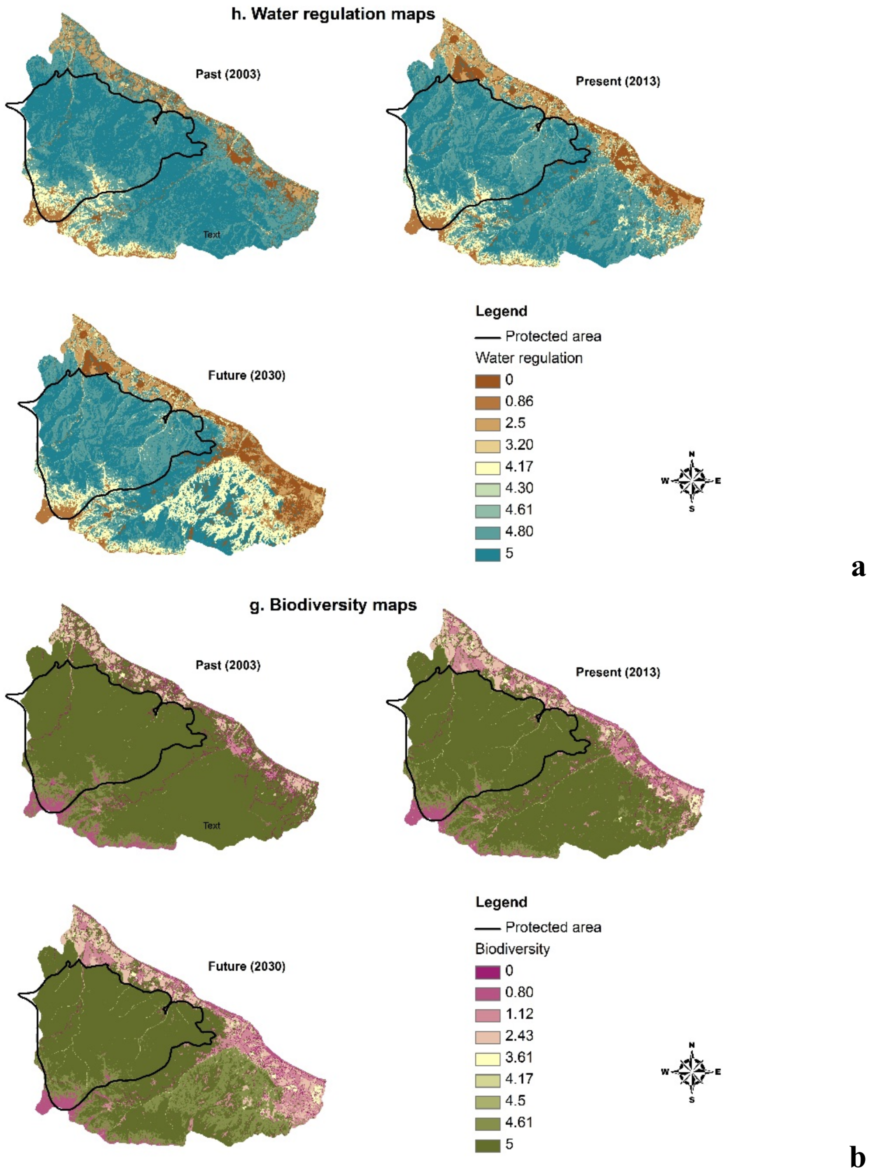
Table 4. Final list of the key ES and their trends based on sampled households responses to interviews. Keys to the status: "++" highly increasing; "+" increasing; "−" decreasing; "−−" highly decreasing; "=" no change.

Type of service	Sub-category	Indicator	Unit of Measurement	Dependency of local people	Recent Trend and intensity	Driver of change
Service group: Provisioning						
Food	Rice	Cultivated land	Ton/ha	Very high	++	Agricultural mechanization, chemical inputs and pesticides
	Fruit	Number of fruit-producing tress	Ton/ha	Very high	+	Chemical inputs and pesticides, forest conversion
	Fish	Abundance in water bodies	Ton or kg catchment in fishing season	Low	−−	Water pollution
	Livestock	Number of livestock per a household	Animal unit	Moderate	−	Urbanization and changing lifestyles
	Honey	Number of beehives	kg	Low	−	Urbanization and changing lifestyles
	Forage	Number of fodder-producing species per ha	Ton/ha	Moderate	+	Reduction of livestock
Raw materials	Timber	Harvestable stock	Ton/ ha	High	−−	Tree smuggling, Forest mismanagement
	Fire wood	Abundance of dead wood resources	Ton/ha Kj/ha	Low	= =	−
water	freshwater	Available water for drinking and irrigation, numbers of rivers and waterways and springs	Ml/ha/year	Very high	−−	Agricultural runoffs, human waste waters
Service group: Supporting and Regulating						
Soil conservation	Erosion control and sediment retention	Net saving soil loss perha	tons/ha/yr	High	−	Land conversion, farmlands mis- management
Water regulation	Water purification	Quality and quantity ofwater	Cubic meter/ha	Very High	−−	Forest conversion to construction and farmland
	Flood control	No. of floods and overflowing in a year	No./ha	High	−	Clear cutting of trees
Climate Regulation	Carbon sequestration	% big trees in hectare	ton/ha/yr	Low	−	Poor forest management
	Air quality regulation	Total leaf area; amountof pollutant in air	Number of polluted day in a year	Low *	−	Forest conversion, urbanization, increased private cars
Biodiversity	Habitat/ refuge for wildlife	Presence of endemic/non endemic species/diverse habitat existing	No. of Plants and animal/ha	High	−−	Irregular hunting and catching, changing natural habitat to anthropogenicareas
Service group: Cultural						
Recreation	Tourism and ecotourism	No of recreation sites	No. of visitors/year	Very high	++	Improving road access and transportation facilities

* Because, in general, air pollution is not considered as a noticeable environmental problem in the study area and the climatic condition is presently desirable.

3.2. Spatial-Temporal Changes of ES Supply associated with LULC Changes

As the potential capacity of each type of LULC to provide ES was scored by experts, it was possible to map and compare the spatial changes of ES supply across the landscape over time. The past LULC of the study landscape is assumed to provide the optimal ES supply for identified priority ES because of the optimal ecological conditions and the minimum human encroachments in the baseline LULC. The present LULC represents current ecosystem service supply from both natural and anthropogenic LULC types. As expected, the highest relative values of ES supply are provided by the natural LULC classes, in particular forest cover and rivers. The current pattern of ES supply will be dramatically changed in the future and the LULC types with high relative values will decline, according to the predicted future LULC. Figure 5 (a–h) shows the spatial-temporal changes for all eight priority ES selected by stakeholders as critical benefits under each of three past, present, and plausible future situations of the Sarvelat and Javaherdasht district.



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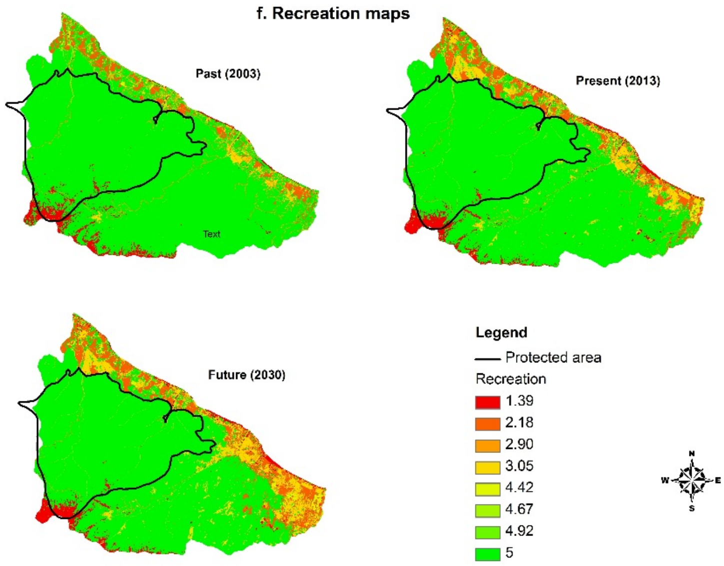

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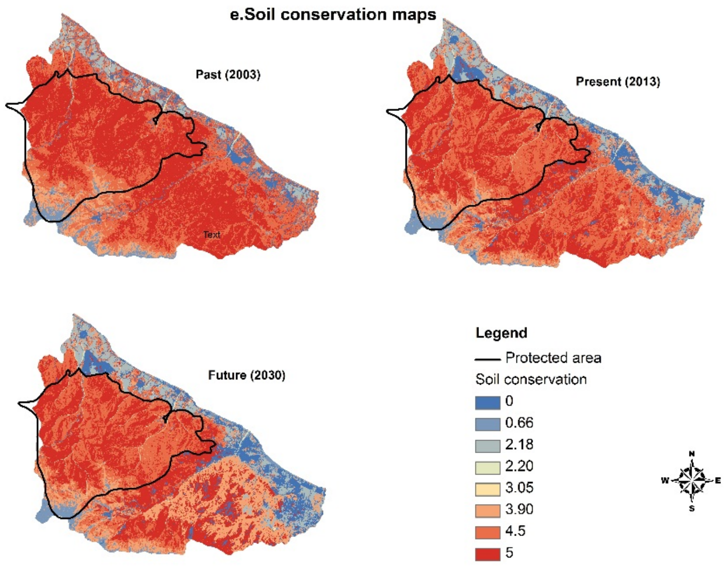

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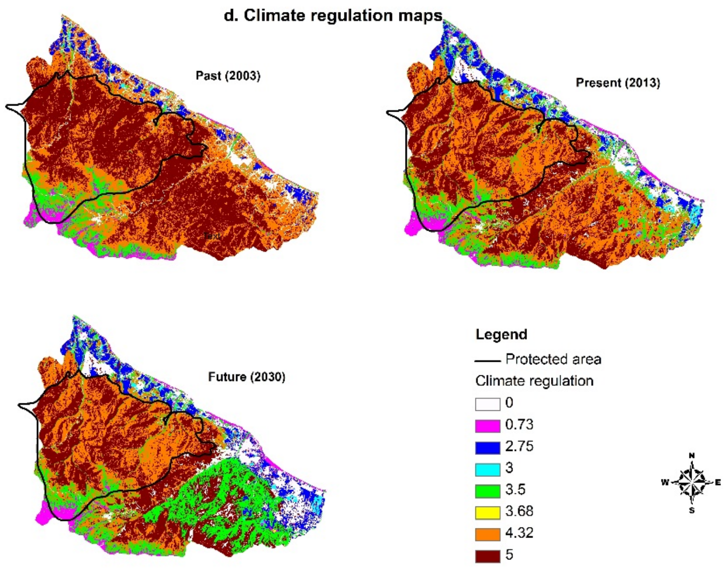

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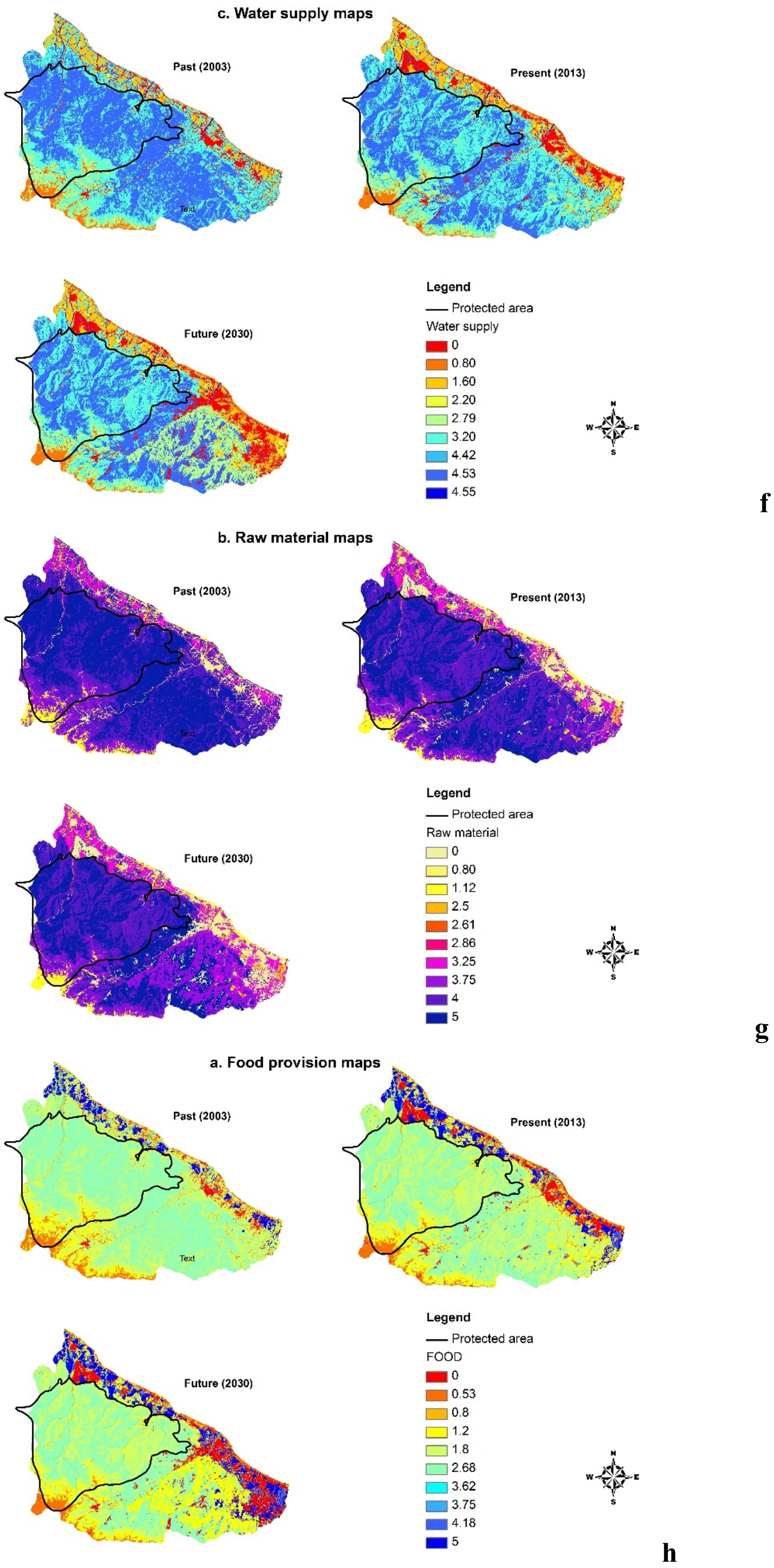

Figure 5. Maps of current, potential, and plausible future supply of ES based on individual service values associated with LULC types and land transformation. Services values are weighted between 0 and 5 based on expert judgment. Services include (**a**) food provision, (**b**) raw materials, (**c**) water supply, (**d**) climate regulation, (**e**) soil conservation, (**f**) recreation, (**g**) biodiversity, and (**h**) water regulation.

There are significant changes in almost all of the eight key ES-relative values of supply between the past and present landscape as well as projected ES supply under the predicted future LULC scenario (Figure 5a–h). The greatest declines are also observed in southern lowland areas under an elevation of 400 m where the most anthropogenic LULC development has occurred. Under the predicted future LULC we will observe a marked negative transformation of ES supply towards higher elevation areas in the eastern parts of the landscape which are the unprotected areas because of limited suitable land availability in the lowlands. However, some parts of high elevation mountainous areas in protected area as well as unprotected areas with elevations of more than 1800 m will remain intact as they are unsuitable for land conversion (Figure 4).

The northern agricultural lands in the study area mostly comprised paddies and mixtures of forest and citrus groves and were ranked as where most food is produced (Figure 5a). Some food provisioning is also recorded in the forest areas, resulting from collection of wild fruit and nuts. In the urbanized north-east of the study area there are more human settlements and little food production is recorded. Figure 5b shows raw material provision in the study area; ranking for this ES ranged from moderate to high throughout the landscape, but was understandably low in both urbanized areas and bare lands. Most water is supplied by Safaroud in the eastern part of the landscape near the external boundary of the protected area (Figure 5c). In addition, forest cover ranked as an area with medium potential for water supply.

Figure 5e,h shows the survey results regarding the importance of regulating services, including soil conservation and water regulation. As demonstrated by these figures, these services are strongly interconnected to each other; there are also strong links to vegetation condition. Mixed-forest citrus groves were ranked higher by experts for their capacity for soil conservation compared to the ranking of the water regulation service provided. There is a need for further quantitative assessment to verify such a distinction. In terms of climate and air quality regulation, forest and woody vegetation land cover types provide the greatest capacity (Figure 5d). Finally, Figure 5g presents how interviewees and experts ranked different land cover types with regard to their importance for biodiversity, specifically regarding habitats and refuges.

3.3. Hotspots for Multiple ES

As others have demonstrated [43–45], because of the inevitable trade-offs between different types of ES, the management of these services should be based on identification of areas that provide the highest level of multiple services (a bundle of services), not on the basis of individual supply of each service. Therefore, in order to identify which locations of the study landscape provide the overall highest average relative values of all eight key ES, all maps were integrated to create an "ES hot-spots" map under all three past, present, and plausible future LULC. To do this, at first all individual maps were overlaid in Arc Gis and the sum of scores was calculated for each LULC. Then the landscape was classified into three classes of low, moderate, and high capacity for providing ES. For this classification we used the Normal Distribution Curve through calculating averages and standard deviation which enables us to identify the separation line between close numerical averages in placing them into each classification of low, moderate, and high capacity (Figure 6). The average relative values to provide multiple ES were standardized using the 33rd and 67th percentiles (Normal distribution curve) for all of the LULC types [46]. For example, if a service scored below the 33rd percentile, it was assigned low; if it scored above the 33rd but below the 67th percentile, it was assigned moderate, and if it scored above the 67th percentile it was rated as high. Figure 7 compares the percentage of each past, present, and plausible future landscape to provide low, moderate, and high capacity for multiple ES supply. This figure identifies many fragmented pieces of the landscape under the current situation in the north-east with high capacity to supply ES, despite significant housing occurring in this area. It is anticipated that these fragmented areas of high ES supply will be significantly impacted in the future as urbanization further expands.

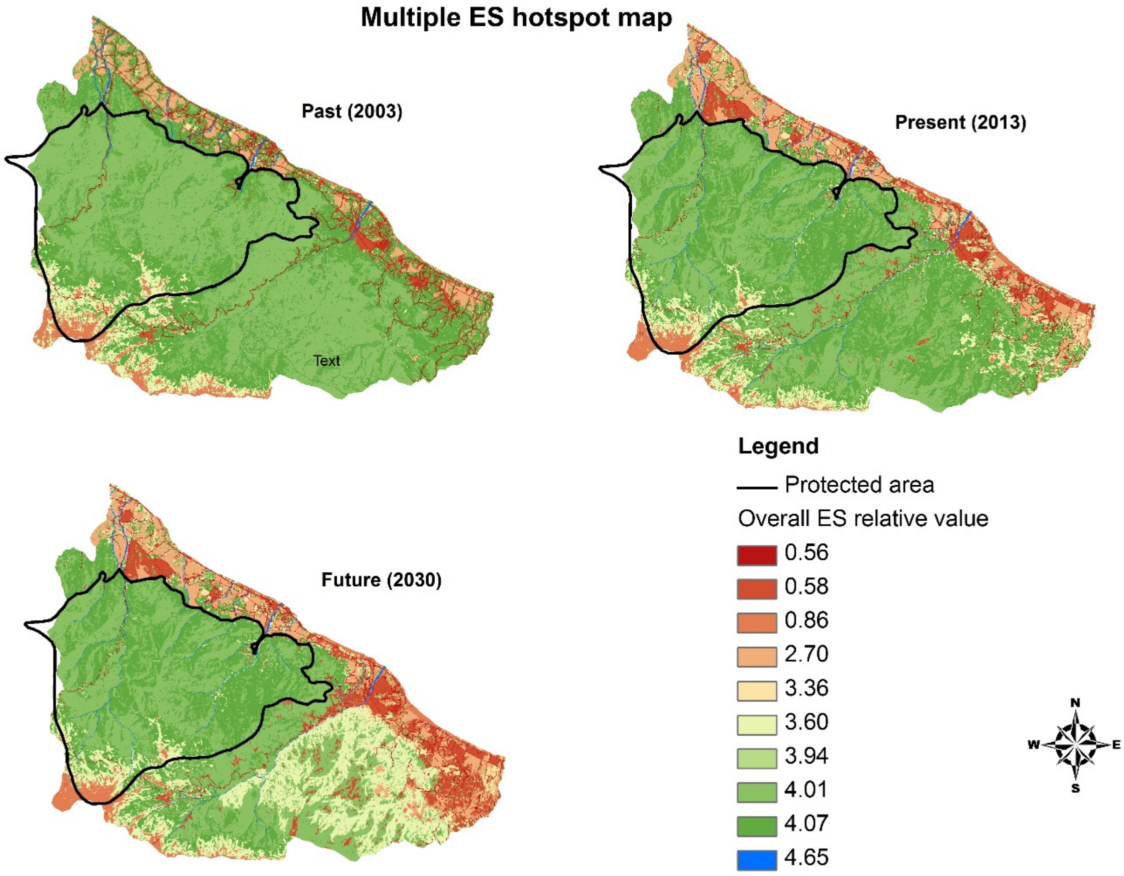

Figure 6. Maps of past, present, and plausible future supply of ES based on multiple service values associated with LULC types and land transformation. Services values are averaged based an integration of all eight individual key ES relative values.

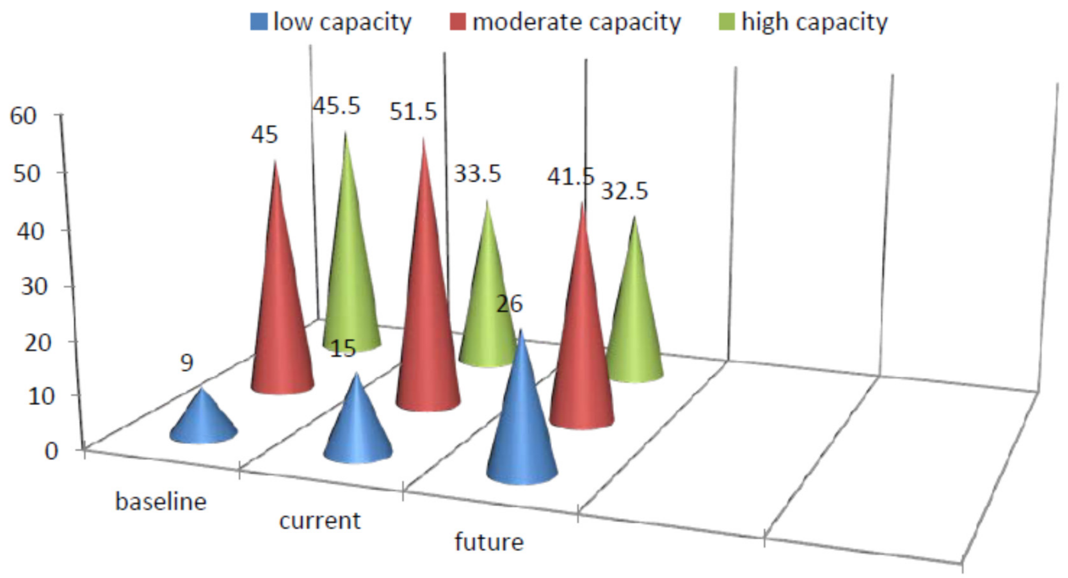

Figure 7. Percentage of the landscape with different relative capacities (low, moderate, and high) for multiple ES supply under each of past, present, and possible future conditions.

As shown in Figure 7, the low capacity areas have increased from 9 under the baseline to 15 under current conditions and it is expected to be increased to 26% in future. The moderate capacity areas have increased from 45 under the baseline to 51% under current conditions while the high capacity area has decreased by 12% at the same time. Under the plausible future scenario we expected a 10% decrease in the moderate capacity area, but the changes in the high capacity area will be minor, as some existing factors, including the presence of the protected area and physiographic parameters such as elevation and slope are considered to prevent or adjust conversion of these areas which usually comprise dense forest and rivers.

4. Discussion

In this study, eight priority ES were mapped based on expert judgment in combination with local community opinions gathered through household surveys and GIS data. This mapping helps planners and policy makers to see in an explicit spatial manner where individual and multiple ES are supplied throughout the 55,829 ha study area. Substantial LULC changes have occurred in the study area over the past decade dominated by conversion of forests to citrus groves and paddies, and subsequent conversion of these agricultural areas to human settlements. Such urbanization trends are readily observed in the eastern part of the study area adjacent to the city of Ramsar and are beginning to spread towards both eastern and northern parts. These changes in LULC have impacted the capacity of the area to supply ES.

Our research demonstrates how descriptive input data collected via consensus-based participatory processes involving both experts and local people can be used in conjunction with satellite imagery and GIS data in ES assessment, particularly in data-poor areas typically found in developing countries. However, the results of such analyses are often subjective and the accuracy depends on the knowledge and experience of the expert or professional for particular landscapes. Moreover, sometimes there are differences between expert opinions and indigenous knowledge, as each of them may have their own priorities.

The study also found that the opinion of communities and experts reflected declines in regulating ecosystem services in the study area. One example is the decreasing quality of water which is supplied and regulated by rivers and forests, caused by agricultural and human waste in the water.

The temporal assessment in this study comparing baseline and current study landscape as well as the future possible LULC shows an increase of some provisioning services including food production and a compensatory decline in other regulating services. Housing is considered to be a critical driver of change in LULC, causing substantial erosion of regulating services. The most significant loss is in soil conservation and water regulation, as well as biodiversity. The consequence of the loss of soil conservation will be felt in the future with decreased water quality and flood mitigation.

In this regard, previous studies have proven that LULC changes, particularly forest conversion to farmland and human settlement, can adversely affect the soil's physical and chemical characteristics and consequently soil quality [47–49]. One important factor in our study landscape which is expected to be influenced by LULC changes is soil erodibility. This is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. It varies from 70/100 for the most fragile soils and 1/100 for the more stable soils [41]. One previous unpublished report in our study area has calculated the average soil erodibility for forest cover to equal 0.07 in soil depths of 0–10 cm [50]. This shows that soil erodibility will increase to about 86% in agricultural land uses in comparison with natural forest covers in the study area. These dramatic changes can certainly impact on soil erosion as well as the decline in water quality in the future. To more accurately estimate the extent of these changes in the study area and its effects on regulating services, sediment retention needs to be modelled in future studies.

Although, the majority of forested and woody land cover still exists, declining trends in the area covered by forest are not yet acute. However, it is assumed that these trends will exacerbate in the future. Importantly, much of these changes are in the areas that border the protected area, with some loss of ES within the protected area. Future changes may further impact the viability of parts of the protected area and this should be of concern to conservation and government organizations.

This study can be compared with previous studies from two different perspectives: firstly, its common methodological approach, and secondly, the results recorded. In terms of methodology, Burkhard *et al.* (2010, 2011) used similar methods to conduct a land cover based assessment of ES similar to that presented here. However, whereas Burkhard *et al.* combined professional opinion with GIS data to produce energy and crop provisioning maps, our study differs because it includes indigenous local knowledge with the perception of ES as supplementary data for expert value judgment; it also comprises a wider range of ES for mapping and assessment. Paudyal *et al.* [27] also present similar work on assessing and mapping ES in central Nepal. However, their study area possesses totally different ecological characteristics and trends, and hence different results are reported. Our results show a declining trend for most ES types because of forest conversion to other land uses, whereas they found the opposite trend in their study.

Our results are also compatible with other previous studies such as O'Farrell *et al.* [51], Paudyal *et al.* [27], Costanza *et al.* [8], de Groot *et al.* [52], and MEA [4], which showed that ES are being lost globally and locally.

One critical issue that we could not investigate in this paper is the potential impacts of climate change on the Hyrcanian forests and the services provided by this unique ecosystem. There is high confidence that a number of weather anomalies and environmental changes observed in the Middle East, including Iran, in recent decades have been caused by global warming. The Hyrcanian threatened relic fauna and flora is considered as one of the most vulnerable biotas to the combined effect of climate and socioeconomic changes, thus becoming a priority target for urgent adaptation efforts [53]. Considering the complex climate factors outside of the immediate region that the region's people have little or no control over, as well as land allocation decisions among different human objectives (regarding land uses), it is obvious that we are at risk of aggravating unwanted trade-offs, and possibly experiencing dramatic changes in provision of ES in the not too distant future. Therefore, there is an urgent need for research that will help to fill the existing knowledge gap related to formulating effective land-based policy to adapt and mitigate the impacts of climate change on this natural forest, its ecosystem services, and human well-being.

Finally, the potential impacts of uncontrolled tourism on the forested areas are high. Local people have begun concentrating their efforts toward tourism and we suggest that conducting more analysis to identify potential synergies and trade-offs between priority ES and different plausible development scenarios is essential.

5. Conclusions

In this study, we applied a rapid, qualitative method previously used by other authors, incorporating several modifications, to a unique forested landscape where no ES assessment had been performed before. In total, 16 ES were identified within the study area and eight of them ranked for their importance by experts and local people. As detailed data to conduct a totally quantified assessment were not available due to resource limitations, the results presented here rely on the knowledge, experience, and judgment of experts and the local community, and therefore, are rather subjective.

During interviews, most of the interviewees believed conservation programs and activities do not achieve their goals in the study area. One reason for this is that the establishment of the protected area cannot be effective by itself if it is not combined with other external plans such as land use planning [54]. In addition, it does not provide tools for prioritizing management alternatives which simultaneously consider the value of ES [55]. This is further compounded by the lack of conservation programs sharing benefits among different stakeholders. Consequently, impacts from a lack of conservation activity have led to the Hyrcanian (Caspian) forests in the study area declining in both quantity and quality.

As specified by this study, the lack of participatory planning and management, which involves the local community in conservation programs as well as incorporating their land-use rights, generated conflicts between the forest dwellers and the administrative authorities. Therefore, formulation of strategies under a flexible participatory approach is unavoidable to enable meaningful stakeholder participation and guarantee secure land tenure, forest user rights, and sufficient financial incentives [14,27]. As a fundamental suggestion to the Iranian government based on our research, the ES assessment approach should be considered as an inseparable part and prerequisite for all land use policy and decision making processes, to stop and reverse declining trends of such services.

In this regard, an assessment of ES demands by local communities compared to ES supply by the forested landscape is required. This can equip planners and decision makers with spatial-temporal data and lead to a revision in management policies to create a balance between these two facets. ES assessment based on this study and method has the capability of promoting public participation and incorporating the public's opinions in conservation programs. Inevitably though, there needs to be concerted efforts to use new tools to address the existing and potential conflicting land uses. This area should be examined with a view to multifunctional land use just as in other parts of the world, where resolutions of such conflicts have been achieved [56]. With regards to the structural characteristics of the Sarvelat and Javaherdasht study area, most ES were found to flow from upstream to downstream areas. As such, future research needs to identify synergies and trade-offs between them, and even among different plausible development options and scenarios, in order to provide the context to design and execute payment mechanisms for ES that could provide a range of options to promote increased conservation of ES within the area in the future.

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Appendix

Table A1. A number of globally significant forested landscapes which have been listed as world heritage area.

Name of world heritage listed forests	Location	Key features	Study on ES (Y, N, Not known)	Study with an indirect emphasize on ES	Key findings	References
Central Sikhote-Alin	Russia	Temperate forests between taiga and subtropics with an extraordinarily high level of endemic plants and invertebrates.	N/Not known	Y	More than 90 percent of the landscape changes occurring in the Sikhote-alin range, home to the densest populations of endangered species in the Russian Far East, are directly due to catastrophic fires. The conversion of forest due to logging and fire has accelerated significantly since 1992.	[57,58]
Wulingyuan Scenic and Historic Interest Area	China	Dense broadleaf forest which is home to some 3000 species of tropical, subtropical and temperate plants, including 600 spp. of woody plants. There are116 species of 50 families of terrestrial vertebrates.	N/Not known	N/Not known	-	-
Canaima National Park	Venezuela	flat-topped mountain formations (tepui) which provide habitat for significant populations of 5 endangered mammal, nearly 29 endemic bird species. The tepuis constitute a unique biogeological entity and are of great geological interest.	N/Not known	N/Not known	-	-
Gunung Mulu	Malaysia	The rainforest contains significant natural habitat for *in situ* conservation of biological diversity and the protection of threatened species.	N/Not known	N/Not known	-	-
Redwood National Park	USA	Old-growth temperate rainforests preserve a number of rare animal species. Numerous ecosystems exist, with seacoast, river, prairie, and densely forested zones all within the park.	N/Not known	Y	The parks' soils contain approximately 89 tons of carbon per acre (200 Mg C per ha), while vegetation contains about 130 tons C per acre (300 Mg C per ha). Restoration activities at the parks (logging-road removal, second-growth forest management) were shown to initially reduce ecosystem carbon, but may provide for enhanced ecosystem carbon storage over the long term.	[59]

Table A1. *Cont.*

Name of world heritage listed forests	Location	Key features	Study on ES (Y, N, Not known)	Study with an indirect emphasize on ES	Key findings	References
Grand Canyon National Park	USA	Boreal Forest ecosystem receives the most rain and snow. Relatively unfragmented and diverse habitat and range of elevations and associated climates which is a valuable wildlife preserve.	N/Not known	N/Not known	-	-
Ha Long Bay	Viet Nam	It is filled with diverse tropical ecosystems including coastal mangrove habitat, coral reefs, sea grass habitat and tropical tree forests. The forest ecosystems house rare wild animals such as deer, mink, squirrels, and monkeys.	N/Not known	N/Not known	-	-
Plitvice Lakes National Park	Croatia	The most beautiful virgin forest of the Dinaric Alps, Čorkova Uvala, is located here. Due to its extraordinary value, this fir forest was proclaimed a special forest reserve. The area is rich in endemic species and habitats, and the morphology and hydrology of the terrain are very specific.	N/Not known	N/Not known	-	-

Table A2. The questionnaire table which was used to determine the most important ES in the study area.

Benefits		Current State (Score 0–5) 5 = Highly Important	Top Five Services in the Current State (Please Tick Five)
Global climate regulation	e.g., carbon storage in trees		
Local climate and air quality regulation	e.g., Providing shade, removing pollutants, influence on rainfall		
Water-related services	Water for human use e.g., domestic human consumption, irrigation, industry, energy		
	Water flow regulation e.g., provision, natural drainage, irrigation, drought /flood prevention		
	Water quality improvement e.g., water purification, waste treatment		
Erosion control	e.g., avoiding landslides		
Coastal protection	e.g., storm protection in coastal areas		
Harvested Wild Goods	**Food** (e.g., fruit, seeds, bushmeat, fish)		
	Fiber e.g., straw, timber,skins, leather, wool *etc.*		
	Natural medicines		
	Energy e.g., firewood, charcoal		
Cultivated Goods	**Food** (e.g., livestock, farmed fish, crops)		
	Fiber e.g., straw, timber, skins, leather, wool etc		
	Energy e.g., biofuels		
Biological control	e.g., regulating pests and vector-borne diseases		
Recreation/tourism			
Aesthetic benefits/inspiration			
Spiritual/religious experience			

Table A3. The questionnaire table which was used to discover trends in changes of priority ES during the recent decade.

Benefit from Appendix s1	How has availability changed over the past 10 Years? Increased ⇧ Stable ⇨ Decreased ⇩	What are the main drivers (causes/factors) of this change

Table A4. The matrix which was used to specify the relationship or disaffiliation between each LULC class and different types of ES.

Services → / Land cover ↓	Food	Raw materials	Water	Genetic resources	Medicinal resources	Ornamental resources	Air quality regulation	Climate regulation	Moderation of extreme events	Waste treatment	Erosion prevention	Maintenance of soil fertility	Maintenance of genetic diversity	Maintenance of life cycles of migratory species	Aesthetic information	Opportunity for recreation & tourism
Agricultura areas	Y	Y	N	Y	N	N	N	Y	N	N	Y	N	N	N	N	N
Human settlements	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Road network	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Rivers and waterways	Y	N	Y	Y	N	N	N	N	N	Y	N	N	Y	Y	Y	Y
Mixed forest and fruit trees	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
Water bodies	Y		Y	Y	N	N	Y	Y	N	N	N	N	N	Y	Y	Y
Forest	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Bare lands	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	Y

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