JOURNAL OF FOREST SCIENCE, *63*, 2017 (7): 300–312

doi: 10.17221/137/2016-JFS

Estimation of the value of forest ecosystem services to develop conservational strategy management (strengths, weaknesses, opportunities and threats)

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Abstract

Jahanifar K., Amirnejad H., Abedi Z., Vafaeinejad A. (2017): Estimation of the value of forest ecosystem services to develop conservational strategy management (strengths, weaknesses, opportunities and threats). J. For. Sci., 63: 300–312.

Forests ecosystems provide several undisputable benefits which policy-makers blink since these values do not record in conventional markets or are difficult to measure. This paper indicates that the annual value of the ecosystem services such as water conservation, soil protection, carbon fixation, nutrient cycling, water purification, air pollution absorption and recreation provided by forests is not only worth millions of dollars, but also in per hectare terms much more than hitherto known. After estimating the value of ecosystem services, results are available to policy-makers and experts at a brainstorming and by using SWOT, conservational strategies for long-term management based on strengths, weaknesses, opportunities and threats were developed. Ecosystem services value for the Mazandaran Forest Reserve ranged from 14.2 to 14.8 million USD or about 6,676.9–6,785.6 USD·ha^{-1}. Given these results, raising the society awareness of the negative impact of forest land use changes based on the functional value were proposed as conservational strategies to prevent the forest land use change. If these are accounted for, then governments and societies faced with the development versus conservation dilemma can create more understanding decisions and policies that will assist to conserve forests and the ecosystem services they provide, and thereby promulgate human well-being and sustainable development.

Keywords: economic valuation; sustainable development; SWOT; Mazandaran Forest Reserve; Iran

Valuation studies have uncovered the significance of forest resources and provided a deeper understanding of many ways in which forest resources benefit mankind (de Groot et al. 2002; Amirnejad et al. 2006). While most of the economists' attention is used on the market value of (certain) forest products, non-market values of forests are now increasingly being appreciated and measured. A significant number of studies on non-market values of forests have been carried out worldwide. This reflects an evolving research agenda that attempts to broaden our understanding of the linkages between the economic and ecological system. As a specific area of practice, ecosystem valuation has recently taken a visible step forward through the work of Costanza et al. (1997) and Daily (1997). While Daily's edited volume provides a diverse set of perspectives on the links between specific ecological services and economic values, Costanza et al. (1997) attempted the more ambitious task of estimating the aggregate economic value of ecosystem services, accounting for all of the benefits that human beings derive from natural systems (Amirnejad et al. 2006). Forests provide several intangible benefits such as regulating local and global climate, protecting watersheds, arresting soil erosion, nutrient cycling, etc. which policy makers ignore since these values do not register in conventional markets or are difficult to measure. While in the past the use, non-use and inherent values were cited to legitimize the conservation of biodiversity and ecosystems, the Millennium Ecosystem Assessment (2005) added another dimension – its role in providing ecosystem services which impact on human well-being and sustainable development (Ninan 2007). In an original paper, Costanza et al. (1997) estimated the total annual value of the world's ecosystem services at an average of 33 trillion USD, and of global forests at 969 USD·ha^{-1}. Despite Iran having the largest ratio of land area under forests among middle income countries in the world, surprisingly there are very few studies which have assessed the economic value of the ecosystem services of Iran's forests, and these too being in Iranians are not easily accessible to the international scientific community. One such study cited recently estimated the total economic value of the ecosystem services of Iran's forests at about 590 billion USD·yr^{-1} (Amirnejad et al. 2006). According to what was said, there should be implemented a strategic planning to conservation and management of this valuable resource. For efficient management and strategic planning, at first, weaknesses, strengths, opportunities and threats are detected.

SWOT analysis has its origins in the 1960s (Learned et al. 1965); it is a simple yet useful planning tool to understand the 'strengths', 'weaknesses', 'opportunities' and 'threats' as part of a strategic planning process. In that planning process various factors influencing the operational environment are diagnosed in details (Kotler 1994). Following that, strategic alternatives are selected in the light of the strengths, weaknesses, threats and opportunities of the organization as determined through internal and external environment analysis (Yüksel, Dagdeviren 2007). SWOT analysis is intended to maximize strengths and opportunities, minimize external threats, weaknesses into strengths and to take advantage of opportunities along with minimizing both internal weaknesses and external threats (Saaty 1987). It is useful especially in preparing for future scenarios and it is economically justifiable in that losses can be minimized. SWOT analysis is often employed when monitoring or evaluating a specific program, service, product or industry and exploring improvement measures (Harrison 2002). Some of the applications of SWOT analysis are included in the private sector as well as in public administration, professional associations and academia (Suh, Emtage 2005). FAO (1989) also formally recognized the SWOT analysis technique as an important participatory assessment tool to be used in gathering, synthesis and analysis of information for community forestry development. The advantages of SWOT analysis are that it is simple and cost efficient. SWOT could generate many ideas which could be useful in summarizing key management issues and opportunities. Through ready countermeasures as outcome, 'strength' could be maximized to overcome weaknesses. Similarly, opportunities are maximized and threats minimized. Though SWOT is simple and cost efficient, the disadvantage is that SWOT analysis is not critically presented. Thus SWOT analysis is needed by maximizing the internal strengths and external opportunities to curb against the internal weaknesses and to counter against external threats. SWOT is also useful in addressing the issue management before it becomes a threat.

The Mazandaran Forest Reserve (MFR) is located in the northeastern region of Iran (Fig. 1). The case study forests extend from Babol in the middle of the Mazandaran province to Behshar in the east and cover the northern slope of the Alborz Mountains with 350 km length and 20–70 km width. The annual growth of the forests differs with regard to the tree species, site, age and density and ranges

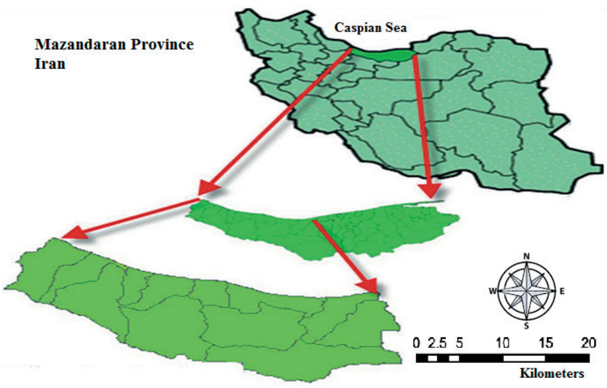

Fig. 1. Location map of the Mazandaran Forest Reserve, north of Iran

from 2 to 8 $m^3 \cdot ha^{-1} \cdot yr^{-1}$ (Abbasi, Mohammadzadeh 2001). The MFR extends in the region ranging from sea level to 2,800 m and mainly consists of mixed forests of beech, maple, oak, hornbeam, and alder. The climate of the region is wet Mediterranean. The average annual temperature of the plateau region is 16–18°C, with high relative humidity especially in summer. Appropriate climatic conditions of the region have made it habitable to many hardwood species. More than 83 tree and 51 shrub species are recognized in the MFR (Mohammadian 2001; Abbasi, Mohammadzadeh 2001). The forest area was estimated to be 1,295,237 ha in the past; today, however, it decreased to 794,014 ha [15% of the total forest area (12.4 million ha)] or 1.1% of the total area of Iran (Mohammadian 2001). Forestry has a relatively long history in Iran, e.g., more than 80 years. Forest management runs on the basis of regulations documented in forest management plans and are provided by the Forest, Range and Watershed Management Organization of Iran. Planned forest management has a history of 40 years in Iran which looks young in comparison with experienced countries having at least 200 years of relevant practices. The areas of forests covered by the plans developed from 450,000 ha in 1988 to 1,300,000 ha in 2010 (Abbasi, Mohammadzadeh 2001). Forest per capita is one of the environmental indices. In Iran, this index is 0.2 ha per person, while globally it is 0.8 ha. This amount indicates poverty and shortage of our country. On the basis of FAO's (2010) statistics, forest areas of 149 and 45 countries were smaller and larger than those of Iran, respectively. Unfortunately, despite the low per capita situation, about one-third of the forests (about 7 million ha) has been destroyed in the last four decades, i.e., 200,000 ha annual deforestation. Of 200,000 ha of our forests, 45,000 ha belongs to MFR (Abbasi, Mohammadzadeh 2001). Reports showed that the rate of deforestation is 2.3 and 1.1% for the north and other parts of the country, respectively (Agheli 2003; Abbasi, Mohammadzadeh 2001).

MATERIAL AND METHODS

Information and data have been collected from related ministries and organizations such as Ministry of Jihad-e-Agriculture, Ministry of Economic Affairs and Finance, Fisheries Organization, Department of Environment and Forest, Range and Watershed Organization. On the other hand, some questionnaires were used. These are indicated at relevant places in the text or references. Seven ecosystem services are assessed. Other benefits such as biodiversity and cultural values, flood protection, pollination and non-timber forest product benefits, etc. are not investigated in our research due to the lack of data or information. To that extent our estimates understate the total value of the ecosystem services provided by the MFR. Although, as stated earlier, the local population is permitted to collect limited quantities of some non-timber forest products (NTFPs) such as wild mushrooms and edible plants from the buffer zone of the forest reserve and these are not registered. Table 1 summarizes the ecosystem services, benefits, valuation methods and norms used in the research. More details are elaborated at relevant places in the text. The data are for the year 2016 or latest available. The estimates in Iranian Rials (IRR) have been converted into USD equivalent using the exchange rate for 2015 (1 USD = 32,000 IRR).

SWOT. There are several approaches in strategic planning to the simultaneous analysis of environmental conditions in an organization or a complex. SWOT analysis is a strategic planning method that is more practical than other methods and brings more understandable results (Suh, Emtage 2005). In this study, quantitative results of the cost-benefit analysis were given to policy-makers, experts, elites and beneficiaries and the preventive strategies and policies to protect and preserve these valuable natural resources were explained and prioritized in a brainstorming process (Yüksel, Dagdeviren 2007). In the selection of the participants in the brainstorming several indexes were considered: (*i*) full familiarity with local conditions in terms of importance, sensitivity and change, (*ii*) the decision and policy making of participants, (*iii*) association with benefits and harms of the changes. Therefore, the participants constitute of 150 high-ranked and middle-ranked managers of Mazandaran Governor's Office, Agricultural Jihad Organization of Mazandaran Province and Department of Natural Resources and Watershed of Mazandaran.

The methodology of the implementation was as follows. Initially, the evaluation matrix of internal and external factors, including opportunities, threats, strengths and weaknesses of change in the area was prepared and then weighted. For weighting, after identifying the internal and external factors, i.e. strengths, weaknesses, opportunities and threats of land use change, each factor was given weight between 0 (unimportant) to 1 (very important). After weighting, the current status of each factor was determined with a score between 1

Table 1. Ecosystem services, benefits, valuation methods and norms

Ecosystem service	Benefit	Valuation method	Valuation procedure
Water conservation	reducing surface runoff	alternative cost	amount of water conserved × the economic cost of storing 1 m^3 of water in a reservoir
Soil protection	controlling erosion	hedonic pricing and opportunity cost	two valuation procedures used: (*i*) forest area valued at the amount of decline in the unit value of forest land due to loss of soil quality/soil nutrients, (*ii*) avoided loss of productive forest land area due to soil erosion × opportunity cost per unit area, i.e. the net annual income from forestry of forestry households in Iran
Carbon fixation	reducing greenhouse effect	market price and damage cost	amount of carbon fixed × two alternative prices: (*i*) carbon price, (*ii*) marginal social damage cost
Nutrient cycling	accumulating nutrients	alternate cost and market price	maintained nutrient (NPK) amount valued at two prices: (*i*) price of green fertilizers, (*ii*) market price of mixed fertilizers in Iran
Water purification	absorbing/ decomposing pollutants	alternate cost	two alternate estimates computed: (*i*) amount of water for domestic use only × unit cost of managing sediments in dams in Iran, (*ii*) amount of water for domestic and industrial use × unit cost of managing sediments in dams in Iran
Air pollution absorption	absorbing air pollutants (SO_2 and NO_2)	alternate cost	SO_2 and NO_2 amount × engineering cost of controlling SO_2 and NO_2
Recreation	recreation	willingness to pay	willingness to pay number of annual visitors to Mazandaran Forest Reserve (MFR) × individual willingness to pay (WTP) for conservation of MFR ecosystem using two alternate prices: (*i*) WTP assuming the status quo conservation scenario, i.e. with core zone constituting 9.2% of the forest reserve, buffer zone 91.8% and a green corridor around the reserve, (*ii*) alternative WTP assuming the full protection scenario, i.e. the entire forest is designated as core zone with no buffer zone

and 4. According to the significance or triviality of internal factors, i.e. the strengths and weaknesses, the scores 4 or 3 and 2 or 1 were appropriated, respectively. In allocating scores, if the strength of the organization is a great, the score 4 is given and if the strengths is normal, the score 3 is given. If the weakness in the organization is a common weakness, the score 2 is given and if it is a critical weakness, the score 1 is given to the factor (Suh, Emtage 2005). For a simultaneous analysis of internal and external factors, the internal and external matrix was used. To create this matrix, the scores obtained from evaluation matrixes of internal and external factors should be inserted in this matrix horizontally and vertically to determine the status of the project in the matrix in order to adopt an effective strategy. Protection strategies were classified in four parts as weaknesses-threats (WT), weaknesses-opportunities (WO), strengths-threats (ST), strengths-opportunities (SO) (Pearce 2001). WO strategies or diversification include suggestions and strategies to compensate for weaknesses with an optimum grasp of opportunities, particularly through the reallocation of resources. ST strategies or revision strategies deal with identifying the internal organizational strengths and tackle the external threats. WT strategies or defensive strategies aim at offering practical solutions and minimizing the weaknesses and avoiding the external threats as well (Yüksel, Dagdeviren 2007).

RESULTS AND DISCUSSION

Water conservation

Forests can keep and hoard water supplied from precipitation in underground aquifers just as water stored in man-made reservoirs. They simplify in increasing the efficient water available, improving water quality, and decreasing water runoff (Xue, Tisdell 2001). The quantity of water conserved depends on several parameters such as evaporation and runoff rates, interception ratios, tree and forest characteristics, nature and intensity of rainfall, geographic and soil conditions, etc. Another study which tried to examine whether coniferous forests evaporate more water than broadleaved forests noted no clear difference, with the interception ratios (of rainfall) for broadleaved forest species ranging from 0.13 to 0.20 and for coniferous forest species from 0.12 to 0.26/0.30 (Komatsu et al. 2007). Spatial heterogeneity of forest ecosystems also impacts on ecosystem services. A simple and straightforward way to estimate the water conservancy performances of forests is to subtract the evaporation/runoff rates from the average annual precipitation rates. Of the average total precipitation in Iran, roughly 62% is conserved, the rest being lost through evaporation/runoffs, etc. The average annual rainfall in the MFR is about 2,250 mm. Using the above parameter (62%), about 1,470 mm of the precipitation received is maintained. To arrive at the quantity of water conserved in the MFR this amount needs to be multiplied by the forest area. Thus the total quantity of water conserved in the forest reserve is about 1,470 mm × 64,632.82 ha, i.e. 1.572 m × 667,148,800 m^2 (since 1 m = 1,000 mm and 1 ha = 10,000 m^2) = 973,812,348 m^3. However, even an alternate landscape can preserve water and therefore what is of particular interest is to know the extra water conserved due to the existence of the forest. In order to value the water conservation or watershed protection functions from the available documents, it is observed that researchers have used different valuation approaches. Kaiser and Roumasset (2002) employed shadow prices derived from an optimization model that related groundwater recharge to forest conservation to evaluate the watershed benefits in Hawaii. However, this requires data on site-specific groundwater recharge rates and groundwater levels which are not readily available. Kramer et al. (1997) applied the avoided flood damage costs to estimate the watershed protection functions of forests in Eastern Madagascar. Xue and Tisdell (2001), Biao et al. (2010), and Mashayekhi et al. (2010) used the cost of storing 1 m^3 of water in a reservoir to value the water conservation function. However, to derive the annual cost of storing 1 m^3 of water, Xue and Tisdell (2001) supposed a life span of 20 years for reservoirs, which seems illusory since reservoirs are assumed to have a life span of 50 years and above. As stated earlier, in order to investigate the economic cost of storing water in a reservoir we need both the direct and indirect costs, which is generally not willingly available in project documents. Though we tried to obtain similar information about the Shahid Rajayi dam built across the Tajan River which originates in the Alborz Mountains, the dam authorities declined to share data on its annual operational and maintenance costs on grounds of confidentiality. The effective storage capacity of the Shahid Rajayi dam is about 180 million m^3. The total cost of the project including indirect costs was 482.55 billion IRR in 2000. Since the inflation rate in Iran is normal, these estimates may be considered as reflecting today's costs. In fact the general price index for Iran which was 109.3 in 2000 (with base 2005 = 100) declined to 97.6 in 2012. As per the dam authorities, the annual operational and maintenance costs of the dam are actually about 729 million IRR (2012). The present value of the total cost of the project was estimated at 489.9101 billion IRR at 2009 prices (at 5% discount rate and supposed project life span of 80 years). However, we may mention that in 2012 yields on long-term (20 years) Iranian government bonds ranged between 2 and 2.5%, which implies that our estimates may be on the conservative aspect. But selecting the appropriate discount rate has been a controversial subject in environmental economics. As David Pearce rightly stated, there is no magic formula to determine the discount rate, and depends on what criteria one adopts to determine this, i.e. whether the opportunity cost of capital, or the borrowing cost of capital, or the social time preference rate. The use of discount rates of 3–6% in real terms has been suggested for assessing irrigation and forestry projects (Pearce 1994; Ninan 2001). Dividing the estimated total cost of the project by the dam storage capacity (180 million m^3) gives a present value estimate of 2,786.705 IRR·m^{-3} of water stored. In terms of annuity this works to 136.1832 IRR·m^{-3} of water stored in a year. Thus the annual economic value of the water conservancy function of the MFR is 973,812,348 m^3 × 136.1832 IRR, i.e. 131.587 billion IRR or 1.375 billion USD (1 USD = 32,000 IRR in 2015–2016).

Soil protection

To estimate the soil protection function of forest ecosystems, one approach is to estimate the extent of the loss of soil nutrients due to soil erosion and then use the replacement cost approach to value the soil protection function. Such an approach has been applied to value the soil protection function of the Chilean temperate forests (Nahuelhual et al. 2007). Although there are some papers which use the hedonic pricing method, these only assess the value of environmental and other factors in urban property prices (Hidano 2002; Gao, Asami 2007). Though a few studies in the USA, Canada, and Europe have tried to study the parameters influencing forest land prices, they have not assessed the role of soil quality or productivity in property prices. But one survey in the USA observed a positive association between soil productivity and farm land prices on the urban fringe near Chicago (Chicoine 1981). A reduction in forest soil quality will impact on the growth of trees and biomass, etc. In this context, a study in the USA mentioned that the quality of land and tree cover, etc., led to a maximum of 17% increase in forest land prices (Snyder et al. 2008). Keeping this in mind, and taking the half value of this parameter (i.e. 17%/2 = 8.5%) it is assumed that a decrease in soil quality will lead to 8.5% decline in the unit value of forest land. The average price of normal forest land in the area where our study area falls was 5,459.8 IRR·ha^{-1} in 2009 (Ministry of Jihad-e-Agriculture 2012). Hence, using the above parameter, the unit value of forest land in the study area is assumed to decrease by 8.5% × 5,459.8 IRR·ha^{-1}, i.e. 461.325 IRR·ha^{-1} due to the loss of soil quality. This value multiplied by the forest area, i.e. 461.325 IRR × 62,302.85 ha, represents the annual economic value of the soil protection function of the MFR which is 28.980 million IRR or 312,295.973 USD. Alternatively we may employ the opportunity cost approach and estimate the economic loss arising from soil erosion. The total amount of soil loss can be calculated by assessing the erosion. A study indicated the erosion difference between woody and non-woody lands to be on average 30 mm·yr^{-1} (Xue, Tisdell 2001). The total amount of soil loss can then be estimated by multiplying this parameter by the total forest area. Thus the total amount of soil loss in the reserve is 32 mm·yr^{-1} × 62,302.85 ha = 19,126,583 m^3·yr^{-1}. Loss of soil adversely affects the productivity of all natural ecosystems. For example, the productivity losses arising from soil erosion in the USA are estimated at over 36.7 billion USD each year. Eroding top soils contain about three times more nutrients than are left in the residual soils. The avoided loss of the productive forest land area due to soil erosion needs to be calculated. Applying this parameter the estimated loss of the productive forest land area due to soil erosion is the total amount of soil loss divided by the average soil thickness, i.e. 19,126,583 m^3·yr^{-1}/2.15 m = 8,821,463.22 m^2, i.e. 869.84 ha·yr^{-1}. We are informed that this considers a linear relationship between soil loss and forest productivity. This underlines the fact that our methods are indefinite and require to be refined based on better scientific data. To estimate the monetary loss, an opportunity cost approach is applied. For this aim, the average income from forestry households in Iran (3,250.9 IRR·ha^{-1} – average for 2012–2015) is employed. Thus the estimated value of the avoided loss of the productive forest land area due to soil erosion is 869.84 ha·yr^{-1} × 3,250.9 IRR·ha^{-1} = 2,983,457.78 IRR·yr^{-1} or 32,261.5 USD·yr^{-1}. Thus the annual economic value of the soil protection function of MFR is about 0.32 million USD or in the alternate case 0.045 million USD.

Carbon fixation

Deforestation subscribes to between 12 and 20% of greenhouse gas emissions every year (van der Werf et al. 2009). Forests adjust the atmosphere by storing carbon and releasing oxygen. Carbon and nutrients accumulate in the forest through complex biogeochemical processes. When forests are cut or burnt, the carbon that they store is released into the atmosphere as CO_2, adding to greenhouse gas emissions. To estimate the carbon fixed in forests most researchers believe in the benefit transfer approach to estimate this value or employ a little rudimentary approach by taking into account only the standing or stem volume, and then derive the carbon ratio of the dry matter of the biomass. As regards, to calculate the amount of carbon fixed in the aboveground biomass of the forest one should take into account not only the standing or stem volume, but also other factors such as biomass expansion factor, wood density, root-to-shoot density and then estimate the carbon ratio of the dry matter of the living biomass, which we have operated in our analysis. The amount of carbon fixed in the MFR annually is estimated at over 114,253 t (Table 2). To value this amount one could apply the carbon tax or the alternate cost of afforestation or the social cost of carbon. In this regard, two alternate approaches are used, the carbon price and the marginal social damage cost, i.e. the economic value of the damage caused by the emission of an additional metric ton of carbon to the atmosphere. The World Bank recently rewarded a price of 4 USD·t^{-1} in carbon credits (t certified emission reduction) for Africa's first big Clean Development Mechanism forest carbon project in Ethiopia. Calculations of the social cost of carbon indicate major variations across studies with an average value of 43 USD·t^{-1} C. Frankhauser (1994) mentions the marginal social damage costs across different studies to range from 6 to 45 USD·t^{-1} C with an average of 20 USD·t^{-1} C. However, marginal costs should have increased significantly since 1994, along with carbon flows and atmospheric carbon stocks. A recent study proposes marginal costs in the 55 to 250 USD·t^{-1} range (Johnson, Hope 2012). Hence,

Table 2. Estimated amount of carbon fixed in Mazandaran Forest Reserve, Iran

Tree species	Aboveground biomass volume ($m^3 \cdot ha^{-1} \cdot yr^{-1}$)	Biomass expansion factor	Wood density ($t\ DM \cdot ha^{-1}$)	Root to shoot density	Carbon fraction	Forest area (ha)	Total carbon fixed (t)
Maple	0.0453	1.22	0.346	0.21	0.4	4,664.78	55.1933
Hornbeam	0.0453	1.46	0.484	0.46	0.4	1,239.81	23.7244
Alder	0.0453	1.46	0.483	0.49	0.4	3,529.27	69.2268
Beech	3.8958	1.26	0.528	0.24	0.4	38,734	72,456.69
White oak	3.8958	1.58	0.678	0.24	0.4	628.5	1,236.63
Other species	3.8958	1.58	0.683	0.24	0.4	14,693.46	28,553.22
Total							114,253.687

DM – dry matter

his study inserted a price of 10 USD·t^{-1} C. We use 4 and alternatively 20 USD to value the carbon fixed by the MFR. As per this the economic value of the carbon fixed by the forest reserve annually is about 408,978.7692 USD or in the alternate case 2,044,893.846 USD.

Our above estimate, nevertheless, has not taken into account the carbon in the ground biomass or soil. Studies propose that old-growth forests accumulate important amounts in the soils (Zhou et al. 2006; Luyssaert et al. 2008). To this extent our estimate of the carbon fixed in the MFR may be considered as a lower bound value. We may, however, mention here that the National Greenhouse Gas Inventory Report (NGGIR) for 2010 for Iran estimated the average carbon stocks for forest soils before conversion in Iran at 83.32 t C·ha^{-1} in 2010. Therefore, in order to assess the extra value of carbon sequestered in forests compared to alternate land uses we have relied on the NGGIR report for Iran, which estimated the biomass stocks and soil carbon stocks for forests and alternate land uses. As per this, the biomass stocks for forest lands (before conversion) in 2015 for Iran was calculated at 144.19 t of dry matter (DM) per hectare (t DM·ha^{-1}) and for croplands at 31.53 t DM·ha^{-1}. Using the carbon ratio (0.5), the carbon stocks for forests were estimated at 65.68 t C·ha^{-1} and for croplands at 16.35 t C·ha^{-1}. Thus, the additional carbon stored in forests compared to croplands is 65.68 – 16.35 t C·ha^{-1} = 56.29 t C·ha^{-1}. Using the two prices (i.e. 5 and 20 USD) discussed earlier to value carbon this additional carbon stored in the aboveground biomass of forests is 210.5 USD·ha^{-1} and in the alternate case 1,110.6 USD·ha^{-1}. The NGGIR estimated the soil carbon stocks in forest lands in 2012 at 86.25 t C·ha^{-1}, and in croplands at 76.45 t C·ha^{-1}, i.e. 7.85 t C·ha^{-1} more in forest lands as compared to croplands. Using the above two alternate prices for valuing carbon sequestered, the additional value of carbon stored in forest soils is 32.24 USD·ha^{-1}, or in the alternate case 166.5 USD·ha^{-1}. Thus, the added value of carbon stored in the ground biomass and soils as compared to croplands is 235.3 USD·ha^{-1} or in the alternate case 1,195.9 USD·ha^{-1}.

Nutrient cycling

Forests provide another important service, nutrient cycling. Trees absorb mineral nutrients from the soil as they grow and accumulate them in their bodies (Xue, Tisdell 2001). As seasons change, some gathered nutrients will return to the soil in withered branches and leaves, and the rest are conserved in the stem and roots (Ninan 1996; Ninan, Inoue 2013). Estimating the nutrient accumulation in forests is not simple since nutrient values change across tree species and age, forest types, soil and site characteristics, seasons, forest management practices, etc. A study in China demonstrated NPK values of 0.155 t and 0.051 t·ha^{-1}·yr^{-1} for needle and broad leaved forest species (Xue et al. 2001). Experimental study in Nagoya, Japan based on nutrient concentrations in leaf litter across seasons indicated average NPK values of 0.01186 and 0.01644 t·ha^{-1}·yr^{-1} for needle leaved and broad leaved forests (Xue et al. 2001). Using these parameters and the biomass productivity, the nutrients (NPK) accumulated in MFR are about 3,426.3362 t·yr^{-1} (Table 3). To estimate the economic value of the nutrients accumulated, two valuation norms are used, the price of green fertilizers (leaf manure), and in the alternate case, that of mixed fertilizers (171,138 IRR·t^{-1} in 2012). However, a study in a forest region in India noted the local price of leaf manure to be 0.40 IRR·t^{-1} in 1988 which worked to about 1.905% of the then price of mixed fertilizer (2,100 IRR·t^{-1}) (Nadkarni 1989). Using this parameter the price of leaf manure for Iran is estimated at 1.91% × 171,138 IRR·t^{-1}, i.e. 2,092.305 IRR·t^{-1} in 2012. Using this price, the economic value of nutrient

Table 3. Estimated quality of nutrient (NPK) accumulated in Mazandaran Forest Reserve, Iran

Tree species	Aboveground biomass ($t \cdot ha^{-1} \cdot yr^{-1}$)	Forest area (ha)	Total aboveground biomass ($t \cdot yr^{-1}$)	NPK ($t \cdot ha^{-1} \cdot yr^{-1}$)	Total NPK ($t \cdot yr^{-1}$)
Maple	0.0324	4,795.78	114.30	0.01256	1.3762
Hornbeam	0.0531	1,233.61	51.44	0.01256	0.6202
Alder	0.0542	3,463.28	129.59	0.01256	1.6283
Beech	3.7695	38,364	164,248	0.01256	2,376.5063
White oak	3.9352	663.5	2,682.29	0.01256	41.5693
Other species	3.9163	14,923.4	57,384	0.01256	936.2783
Total nutrients accumulated					3,426.3362

cycling in the forest reserve is 6.877 million $IRR \cdot yr^{-1}$ or 0.069 million $USD \cdot yr^{-1}$, and if we insert the price of mixed fertilizers, this value is 581.861 million IRR or 6.220 million $USD \cdot yr^{-1}$. However, the above estimate accounts for only a part of the nutrients accumulated in the forest. Some of the nutrients in the aboveground biomass will also filter to the soil through litterfall, etc. In order to find out the additional value of nutrients in forests versus an alternate landscape, we have compared the estimated values for our forest reserve with plantation forestry. Using the NPK values for different species presented in Table 3, and the prices of leaf manure and chemical fertilizers discussed earlier, the added value of nutrients accumulated in MFR is 0.59 $USD \cdot ha^{-1}$, and in the alternate case 48.65 $USD \cdot ha^{-1}$.

Water purification

Forest soils and root systems, and microorganisms present in soil and water help in filtering and absorbing contaminants and harmful bacteria from the water received from precipitation. In fact, the water received from rainfall in forest areas that drips through streams and springs is rich in mineral nutrients and highly valued for its purity and medicinal value (Ninan 2011). The soil and water conservation, and water purification are interrelated as these are different services provided by forest ecosystems, and need to be accounted for to measure the total economic value of forest ecosystem services. To estimate the water purification services provided by the MFR, we have investigated the annual effective water supply by water utilities for domestic purposes and in an alternate case the quantity used for domestic and industrial purposes in 2015. These are 198 and 613 million m^3, respectively. To estimate the economic value of the water purification function of forests, we need to know the unit cost of controlling sediments in dams. But no such data are willingly available. Sedimentation will adversely affect the water quality, reduce the effective storage capacity and life of reservoirs and corrode hydropower turbines. However, deforestation or natural disasters such as landslides can make these expectations go awry to get an idea of the cost of managing sediments in dams. While the storage capacity of this dam is 199 million m^3, the effective storage capacity is 189 million m^3. The difference, i.e. 10 million m^3, may be considered as the dam space for collecting sediments, which is 5.2% of the reservoir capacity. As noted earlier, the estimated annual cost of storing 1 m^3 of water in this dam is 145.15 IRR. Of this 5.2%, i.e. 7.15 $IRR \cdot m^{-3}$, may be attributed to the cost for managing sediments in the dam. Using this unit cost, the annual economic value of the water purification function of the MFR is 198 million $m^3 \times 7.15\ IRR \cdot m^{-3}$ = 1,426,850,000 IRR or 16.104 million USD or in the alternate case, 617 million $m^3 \times 7.15\ IRR \cdot m^{-3}$ = 4,410,700,000 IRR or 45.845 million USD.

Air purification

Trees absorb and decompose damaging gases such as SO_2, NO_2 and other harmful gases through the plant's special organs and physiological performance. Forests thus support an air purification function. The pollution absorption capacity of trees varies depending on tree, forest and site characteristics, location, seasons and weather conditions, pollution levels, etc. A study in China investigated average annual absorption rates for SO_2 at 88.65 and 215.6 $kg \cdot ha^{-1}$ for broadleaved and coniferous forests, respectively (Xue, Tisdell 2001). However, a study of air pollution removal by urban trees in Guangzhou, China presented removal rates of 23.8, 24.3 and 88.8 $kg \cdot ha^{-1} \cdot yr^{-1}$ for SO_2, NO_2 and total suspended particulates in recreational areas of the city (Jim, Chen 2008). A study which studied the gas sink services of field and mountainous areas in Japan reported annual absorption rates of SO_2 and NO_2 at 11.1 and 16.2 kg·ha^{-1}, respectively (Yoshida 2001). These parameters (i.e. 11.1 and 16.2 kg·ha^{-1}) multiplied by the total forest area and then by the engineering cost of controlling SO_2 and NO_2 (272,000 and 1,258,000 IRR·t^{-1}, respectively) give the economic value of the air purification functions of the MFR. These annual values are 179.5 million IRR (1.9 million USD) and 1,201.12 million IRR (12.65 million USD) for SO_2 and NO_2, respectively or the total value of 15.1 million USD·yr^{-1}. Air pollutants will also be absorbed by alternate landscapes such as paddy lands. To get an idea of the extra value of air pollutants absorbed by forests as contrasted to paddy lands we have used the annual absorption rates of SO_2 and NO_2 for forests and paddy lands in Iran (Yoshida 2001). The respective rates were 11.1 and 16.2 kg·ha^{-1} for forests, as mentioned earlier, and 10.09 and 13.89 kg·ha^{-1} for paddy lands. Using the above parameters and the engineering costs for controlling SO_2 and NO_2 discussed earlier, the annual value of SO_2 and NO_2 absorbed by forests was 2,914.6 IRR·ha^{-1} (or 31.12 USD·ha^{-1}) and 18,958 IRR·ha^{-1} (or 202.34 USD·ha^{-1}), respectively. For paddy lands these values were 2,634.36 IRR·ha^{-1} (28.04 USD·ha^{-1}) and 17,215.1 IRR·ha^{-1} (189.65 USD·ha^{-1}), respectively. Based on these estimates, the additional annual value of air pollutants (SO_2 and NO_2) absorbed by forests compared to paddy lands in Iran was 21.5 USD·ha^{-1}.

Recreation

Forests also provide recreational benefits. The MFR covering some areas attracts many tourists and visitors because of its scenic beauty, mountains, marshlands, and lakes. During 2013–2016 the park attracted an average of 0.55 million visitors per year. Although there are no entrance fees to the parks, visitors incur expenditure for travel, board and lodging besides their time. However, data on these expenditures are not available. To estimate the economic value of the recreational benefits, we have used two alternate prices. In one case we have multiplied the number of visitors to the park by the individual willingness to pay for the conservation of Oku Aizu forest ecosystem demonstrated in a recent survey which was 3,256 ¥ per person per year assuming the status quo conservation scenario, i.e. the core zone constituting 9.4% and the buffer zone 91.8% of the forest reserve, and a green corridor around the forest reserve; and in the alternate case 6,532 ¥ per person per year assuming the full protection scenario, i.e. the entire forest is nominated as the core zone with no buffer zone (Yoshida 2001). On this basis, the annual economic value of the recreational benefits of the MFR is 1.191 billion IRR or 10.62 million USD and in the alternate case 2.63 billion IRR or 26.4 million USD.

Total economic value of ecosystem services

A summary of the estimates of the total economic value of the seven ecosystem services provided by MFR is presented in Table 4. We have two sets of estimates using alternate methods or prices. Estimate 1 includes the lower level of the two sets of the estimated values of ecosystem services, whiles estimate 2 includes the higher level of the two sets of values so as to demonstrate the range of the estimated values. As seen from Table 4, this annual value of the seven ecosystem services evaluated ranges from 1.432 to 1.490 billion USD or about 16,863 to 18,321 USD·ha^{-1}·yr^{-1}. The limitations of monetary values and non-market valuation may be noted. These values are also sensitive to the prices and methods used. As Braat and de Groot (2012) observed: the limitations of monetary valuation are many, if only that the currencies employed may be fully unstable, the market-based methods bear from the same flaws as the markets themselves, and when ecosystems are near critical thresholds and ecosystem change is irreversible, money values do not assist as a regulatory mechanism.

SWOT

As previously mentioned, according to the quantitative results of the economic valuation of forest ecosystem services in MFR in face of land use change, the evaluation matrix of internal and external factors was created to identify weaknesses, strengths, opportunities and threats of land use change and forest habitats of the MFR (Table 5).

Using the SWOT matrix, the data related to internal factors (strengths and weaknesses) and external factors (opportunities and threats) were compared with regard to the matrix strategies and different strategies were presented. Comparison of the major internal and external factors is the most difficult parts of making the SWOT matrix in which the matching of strengths, weaknesses, threats and opportunities exists and good judgments are needed. In applying this matrix an effort was made to devel-

Table 4. Summary of the total economic value of ecosystem services provided in Mazandaran Forest Reserve (MFR), Iran

Ecosystem service	Annual value (2016) (million USD)	
	estimate 1[a]	estimate 2[b]
Water conservation	1,384.634	1,382.453
Soil protection	0.063	0.769
Carbon fixation	0.672	3.638
Nutrient cycling	0.104	9.132
Water purification	15.168	44.372
Air pollutant absorption	11.759	14.869
Recreational benefits	12.853	26.836
Total	1,432.739	1,490.825

[a]Estimate 1: (*i*) water conservation – volume of water conserved by the forest reserve valued at the economic cost of storing 1 m^3 of water, (*ii*) soil protection – the extent of avoided loss of productive forest land area due to soil erosion valued at the opportunity cost of land, i.e. the net annual income from forestry of forestry households, (*iii*) carbon fixation – annual amount of carbon fixed valued at carbon price, (*iv*) nutrient cycling – NPK accumulated valued at unit price of leaf manure, i.e. the ratio of price of leaf manure to price of mixed fertilizer × price of mixed fertilizers, (*v*) water purification – volume of water for domestic purposes valued at the unit cost of managing sediments in dams (i.e. $IRR \cdot m^{-3}$), (*vi*) air pollution (SO_2 and NO_2) absorption – amount of air pollutants absorbed valued at the engineering cost of controlling SO_2 and NO_2, (*vii*) recreational benefits – number of annual visitors to MFR valued at the individual willingness to pay for the conservation of MFR ecosystem assuming the status quo conservation scenario, i.e. with core zone constituting 8.9% of the forest reserve, buffer zone constituting 91.2%, and a green corridor around the reserve. Except for water conservation and air purification, for all ecosystem services evaluated, we have two sets of estimates using alternative methods or prices. Estimate 1 includes the lower level of the two sets of the estimated values of ecosystem services; [b]Estimate 2: the same as above except the following: (*i*) soil protection – forest area valued at the amount of decline in the unit value of forest land (in $IRR \cdot ha^{-1}$) due to the loss of soil quality/soil nutrients, (*ii*) carbon fixation – annual amount of carbon fixed valued at the marginal social damage cost, i.e. the economic value of the damage caused by the emission of an additional metric ton of carbon in the atmosphere, (*iii*) nutrient cycling – NPK accumulated valued at the unit price of mixed fertilizers, (*iv*) water purification – volume of water used for domestic and industrial purposes valued at the unit cost of managing sediments in dams ($IRR \cdot m^{-3}$), (*v*) recreational benefits – number of annual visitors to MFR valued at the individual willingness to pay for conservation of MFR assuming the full protection scenario, i.e. the entire forest reserve appointed as core zone with no buffer zone. Except for water conservation and air purification, for all ecosystem services evaluated, we have two sets of estimates using alternative methods or prices. Estimate 2 includes the higher level of the two sets of the estimated values of ecosystem services

Table 5. Matrix evaluation of the internal and external factors

Strategic factors	Normalized weight	Score	Weighted score
Strengths (S)			
S_1: unique environmental features	0.066	3	0.198
S_2: existence of forest stocks	0.094	2	0.188
S_3: recreational resorts	0.077	3	0.231
S_4: governmental organizations and NGOs for protection	0.093	3	0.297
Weaknesses (W)			
W_1: ecological and environmental vulnerability of the area	0.085	1	0.085
W_2: lack of legislation on ownership rights	0.055	2	0.11
W_3: lack of coordination in executive organizations	0.063	2	0.126
W_4: insufficient protective facilities in spite of the area vastness	0.49	2	0.098
W_5: insufficient cultural and moral training for proper use	0.066	1	0.066
Opportunities (O)			
O_1: income creation	0.095	4	0.38
O_2: the attention of authorities to forest protection	0.041	3	0.123
O_3: raising public awareness of the real value of forests	0.071	3	0.213
O_4: availability of environmental functions	0.032	3	0.096
Threats (T)			
T_1: land scarcity	0.063	4	0.252
T_2: pressure on trespass to land by governmental speculators and rentiers	0.071	3	0.213
T_3: acts of Godlike flood and conflagration	0.073	3	0.219
T_4: lack of efficient systems for the exploitation of natural resources	0.063	4	0.252

NGO – non-governmental organization

op useful strategies drawing on the ideas of policy-makers and elites using brainstorming to ensure the implementation of the internal and external factors. After determining and scoring the internal and external factors, these factors were placed in Table 6 to adopt the required strategies.

In addition, using different weights of criteria and sub-criteria and performance strategy, the protection policies for the MFR were developed.

Table 6. SWOT matrix

	Weaknesses (W)	Strengths (S)
	conservational strategies	
Opportunities (O)	WO	SO
Threats (T)	WT	ST

WO – availing from environmental opportunities to reduce internal weaknesses; WT – (i) considering the quantitative value of ecosystem goods and services in the case of change, (ii) allocating natural areas with priority of low functional value and minimum external costs, (iii) media advertising and public awareness about the crucial role of forest lands from various aspects, (iv) upgrading the equipment and technology in the land monitoring units, (v) increasing surveillances on the organizations concerned with land management and sustainable development, (vi) raising the public participation with media and cultural campaigns; SO – availing from internal strength points to grasp and exploit the environmental opportunities; ST – availing from internal strength points to reduce and eradicate environmental threats

CONCLUSIONS

The benefits provided by the MFR are significant. Even without considering habitat, biodiversity and cultural values, flood protection, pollination and NTFP benefits, etc., the total annual economic value of the ecosystem services estimated by this forest reserve is worth millions of USD. If these are reckoned in decision making, it could lead to better conservation consequences. We are, however, aware that like most, if not all, forest valuation researches we have mostly introduced the total ecosystem service benefits of conserving forests rather than the added value or the difference in the benefits of conserving forests vis-a-vis their alternate uses. Such an analysis would have provided the economic justification for conserving forests vis-a-vis their alternate uses. However, this would need significant resources and time, and scientific studies and field data to evaluate, for example, the water and carbon sink services provided by intact forests versus their alternate uses. In this context, Beukering's et al. (2003) paper of the Leuser National Park in Indonesia is noteworthy in that they surveyed the benefits of the park under three alternative scenarios – deforestation, conservation and selective use. Their results (accumulated total economic value at 3% discount rate over 30 years) stated that the conservation option was most beneficial (9,538 million USD) compared to selective use (9,100 million USD) and deforestation (6,958 million USD). Using available evidences, our study shows that the quality of water retained, carbon sequestered, nutrients accumulated and air pollutants absorbed by forests are higher than in alternate land uses. This lends support to the economic case for conserving forests. Here it is also worth noting that in 2006, the Indian Supreme Court directed the setting up of compensatory payments for the conversion of different types of forested land to non-forest uses. These payments are to be made to an afforestation fund to develop India's forest cover. Notwithstanding the limitations cited earlier, our results establish that the ecosystem service benefits from forests are significant which policy-makers cannot throw down. Governments and societies faced with the development versus conservation dilemma need to factor in this while making decisions that impact on natural resources and ecosystems. Realization of these significant intangible benefits will assist in more informed decisions and policies that will help conserve forest ecosystems and the services they provide as well as promote human well-being and sustainable development.

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Received for publication December 14, 2016
Accepted after corrections May 23, 2017