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How much is the use values of forest ecosystem services? Case study: north forests of Iran

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ABSTRACT

Forests play a significant role for human's well-being. Economists' attention is mostly drawn on the market value of forest products. The trend, however, is changing as non-market values of forests are increasingly appreciated and measured. Recently, the ecosystem value of forest has been studied by natural resource economists and its role on human welfare is ensured. This paper indicates that the annual use 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. This value for the Mazandaran forest reserve (MFR) ranged US$ 14.2–14.8 million or about US$ 6676.9–6785.6 per ha. 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 conserve forests and the ecosystem services they provide, and thereby promulgate human well-being and sustainable development. Realization about 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.

Key words: Economic valuation, Forest ecosystem services, Sustainable development, Mazandaran forest reserve.

INTRODUCTION

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 conservation of biodiversity and ecosystems, the Millennium Ecosystem Assessment (MEA 2005) added another dimension–viz., 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 US$ 33 trillion, and of global forests at US$ 969 per ha. Despite Iran having the largest ratio of land area under forests among middle income countries in the world, surprisingly there are very few studies assessing the economic values of the ecosystem services of Iran's forests, and these are not easily accessible to the international scientific community (Agheli 2003). One such study cited recently estimated the total economic value of the ecosystem services of Iran's forests at about US$ 590 billion per annum (White *et al.* 2011).

This paper, therefore, makes a case study to estimate the economic value of the ecosystem services of forests in North of Iran. The Mazandaran Forest Reign is of great importance from various aspects regionally and internationally. Economically speaking, we can point out to its employment capacity, wood and timber supply and medicinal plants for the native dwellers (Turner *et al.* 2007). From the environmental aspects, protecting biodiversity, genetic storage, ecosystem services and microclimate adjustment are important as a result of commercial use of the forests, undue cuts-off and exploitation (Wegner & Pascual 2011; Nasiri *et al.* 2012). There have been numerous threats over the years and led to a significant decrease in the extent and quality of this living fossil. This trend will exert an irreparable damages nationally and internationally (Yousefi *et al.* 2011). So that, we are aware of the limitations and criticisms leveled against economic valuation and conventional cost-benefit analysis, along with the need for leaning on plural approaches to justify conservation of biodiversity and ecosystem services (Norgaard 2010).Economic valuation, however, does not connote that other perspectives for better management of the environment have to be overlooked. All that it seeks to convey is that if proper values are allocated to environmental goods and services, it would lead to better conservation consequences. However, market values tend to be precise monetary values, but are highly incorrect as measures of social costs and benefits (Amirnejad *et al.* 2006).

Estimated monetary values of ecosystem services are ambiguous, but recuperate accuracy by making the combined market and non-market values better reflect actual costs and benefits. Moreover, the estimated values of ecosystem services will change with changes in quantity, incomes, prices and methods used to evaluate these services. These points may be born in mind while evaluating the estimated values of forest ecosystem services for North Iran.

MATERIALS AND METHODS

The Mazandaran forest reserve (MFR) located in the north-east region of Iran (See Fig. 1). The case study forests, extend from Babol City in the middle of Mazandaran Province to Behshar City 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 respect to the tree species, site, age and density, ranged from 2 to 8 m^3 ha^{-1} in a year (Abbasi & Mohammadzadeh 2010). The MFR extends the region ranging from sea level to 2800 m and mainly consists of mixed forests of beech, maple, oak, hornbeam, and alder (Abbasi & Mohammadzadeh 2010). 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 the summer. Appropriate climatic conditions of the region have made it habitable to many hardwood species. Over 83 tree and 51 shrub species are recognized in the MFR (Mohammadian, 2001; Abbasi & Mohammadzadeh 2010). The forest area was estimated to be 1295237 ha in the past. Nowadays, however, it decreased to 794014 ha [15% of the total forest area (12.4 million ha)] or 1.1% of the total area of Iran (Mohammadian 2001). Forest per capita is one of the environmental indices. In Iran, this index is 0.2 ha per person, in comparison with 0.8 ha globally. This amount indicates poverty and shortage of our country. On the basis of FAO reports in 2011, forest areas of 149 and 45 countries were lower and higher than Iran, respectively. Unfortunately, despite the low per capita situation, about one-third of the forests (about 7 million ha) has been destroyed in the recent four decades, i.e., 200,000 ha annual deforestation. Of 200,000 ha of our forests, 45,000 ha belongs to MFR (Abbasi & Mohammadzadeh 2010). Reports showed that the rate of deforestation is 2.3% and 1.1% for north and other parts of the country, respectively (Agheli 2003; Abbasi & Mohammadzadeh 2010).

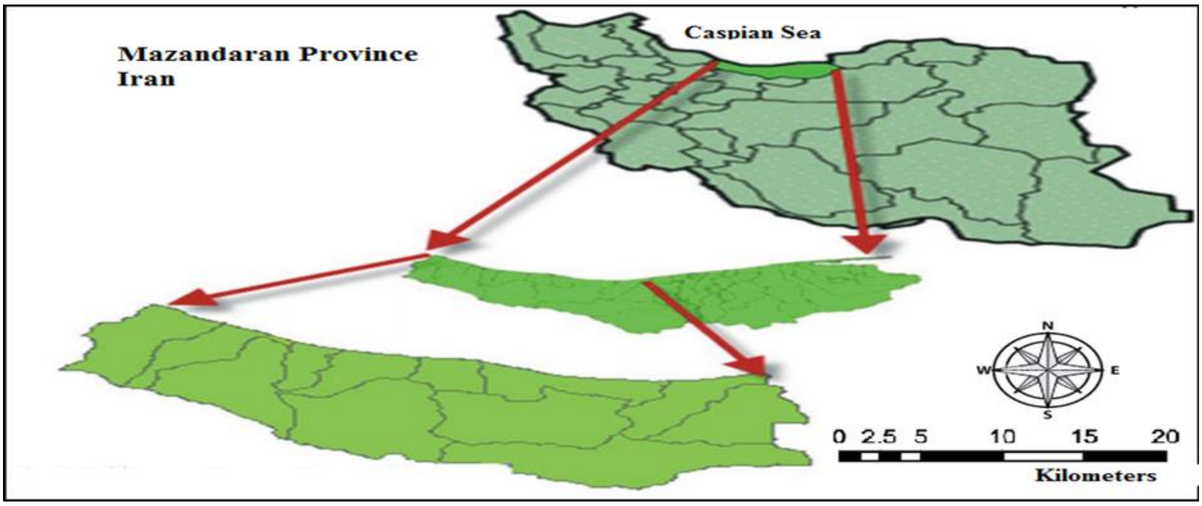

Fig. 1. Location map of Mazandaran forest sources, north of Iran.

Information and data were collected from related ministries and organizations such as Iranian Ministry of Jihad-e-Agriculture, Iranian Ministry of Economic Affairs and Finance, Iranian Fisheries organization, Iranian Department of Environment and Forest, Range and Watershed Organization as well as employing some questionnaires. Cochran's (1977) formulae were also used to estimate sample numbers and random sampling method.

The sample number was determined on the basis of the mean and statistical population variance of 50 pretest. These are indicated in relevant places in the text or references. Seven ecosystem services were assessed. Other benefits such as biodiversity and cultural values, flood protection, pollination and Non-Timber Forest Product (NTFP) benefits were not investigated in the present study due to lack of data or information. To extent our estimates understate the total value of the ecosystem services provided by the MFR. Although, as stated earlier, local population are permitted to collect limited quantities of some NTFPs such as wild mushrooms and edible plants from the buffer zone of the forest reserve, these data were not registered. Table 1 summarizes the ecosystem services, benefits, valuation methods and norms used in the research. More details are elaborated in relevant places in the text. Data belonged to 2014 or latest available. The estimates in Iranian Rials (IRR) have been converted into US$ equivalent using the exchange rate for 2015 (1 US$ = 24700 Rials).

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 run-off (Xue & Tisdell 2001). The quantity of water conserved depends on several parameters such as evaporation and run-off rates, interception ratios, tree and forest characteristics, nature and intensity of rainfall, geographic and soil conditions, etc.

Although one would expect interception ratios and evaporation rates to differ across forest types and species, a study tried to assess the relationship between rainfall and interception ratios for forests in Iran (Komatsu *et al.* 2008).

In another study, examining whether coniferous forests evaporate more water than broadleaved forests, no clear difference was reported, 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. For instance, study on a forest ecosystem in Beijing, China revealed that forests located in the plain area or lower altitude had the highest soil water storage capacity compared to those located in the hills or higher altitudes (Biao *et al.* 2010).

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

Ecosystem service	Benefit	Valuation methods	Valuation procedure
Water conservation	Reducing surface run-off	Alternative cost and Meta-Analysis Benefit Transfer	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: (a) Forest area valued at the amount of decline in the unit value of forest land due to loss of soil quality/soil nutrients; (b) 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, damage cost and Meta-Analysis Benefit Transfer	Amount of carbon fixed × two alternative prices: (a) Carbon price; (b) Marginal social damage cost
Nutrient cycling	Accumulating nutrients	Alternate cost and market price	Maintained nutrient (NPK) amount valued at two prices (a) price of green fertilizers; (b) market price of mixed fertilizers in Mazandaran Province.
Water purification	Absorbing/ decomposing pollutants	Alternate cost	Two alternate estimates computed: (a) Amount of water for domestic use only × unit cost of managing sediments in dams in Mazandaran Province, and; (b) Amount of water for domestic and industrial use × unit cost of managing sediments in dams in Mazandaran Province.
Air pollution absorption	Absorbing air pollutants (SO_2 and NO_2)	Alternate cost and Meta-Analysis Benefit Transfer	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 MFR × Individual Willingness to Pay (WTP) based on contingent valuation (CV) for conservation of MFR ecosystem using two alternate prices (a) WTP assuming 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, (b) alternatively WTP assuming full protection scenario, i.e., entire forest is designated as core zone with no buffer zone.

Present study indicated further that forests located on steeper slopes intercepted the largest ratio of rainfall, followed by forests located in flat slope and slanting slope, while those forests with gentle slope only intercepted a minor proportion of rainfall. In present study it was also found that by increasing in the slope angle, the interception capacity of forest ecosystem decreased awhile. However, data on many of the aforementioned parameters are not promptly available or difficult to calculate, thus need considerable data and time to evaluate. A simple and straight forward way to estimate the water conservancy performances of forests is to subtract the evaporation/run-off rates from the average annual precipitation rates. Of the average total precipitation in Iran, violently 62% is conserved, the rest being lost through evaporation/run-offs, etc. The average annual rainfall in the MFR is about 2250 mm. Using the above parameter (62%), about 1470 mm of the precipitation received is maintain. To arrive at the quantity of water conserved in the MFR, this amount needs to be multiplied with the forest area. Thus the total quantity of water conserved in the forest reserve is about 1470 mm × 64,632.82 ha i.e. 1.572 m × 667,148,800 m^2 (since 1 m = 1000 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. Although we have not been able to estimate this for our study area due to lack of data, evidences suggest that annual sediment yields and erosion rates are larger in Iranian Cypress Plantations compared to undisturbed forests or broadleaved forests, implying that, the quality of water maintained in planted forests is lower than in broadleaved forests (Mizugaki *et al.* 2007; Ide *et al.* 2009). In order to evaluate the water conservation or watershed protection functions, from the available documents, it is observed that researchers have used different valuation approaches. Kaiser & Roumasset (2002) employed shadow prices derived from an optimization model relating to groundwater recharge for 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 & Tisdell (2001), Biao *et al.* (2010) and Mashayekhi *et al.* (2010) have employed the cost of storing 1 m^3 of water in a reservoir to evaluate the water conservation function. However, to derive the annual cost of storing 1 m^3 of water, Xue & Tisdell (2001) have 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 higher. They have also not discounted the stream of costs incurred by the area which is incumbent to calculation for inflation and the time value of money. Moreover, authors in these four studies have considered only the direct costs of dam construction and maintenance, whereas to assess the economic cost of storing water in a reservoir, both direct and indirect costs require to be calculated for keeping in view data availability and limitations (after overcoming gaps of earlier studies), i.e., the economic cost of storing 1 m^3 of water in a reservoir to evaluate the water conservation function of the MFR. As mentioned before, investigating the economic cost of storing water in a reservoir needs both the direct and indirect costs, which is generally not willingly available in project documents, because such its cost is more reflective of current construction costs. Though we tried to obtain similar information about the Shahid Rajayi dam built across the Tajan River, Mazandaran Province, Iran, originated from 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 IRR 482.55 billion in 2000. Since the inflation rate in Iran is normally, these estimates may be considered as reflecting the costs. In fact, the general price index in Iran which was 109.3 in 2000 declined to 97.6 in 2012. As per the dam authorities, the annual operational and maintenance costs of the dam is actually about IRR 729 million (2012). The present value of the total cost of the project was estimated at IRR 489.9101 billion at 2009 prices (at 5% discount rate and supposed project life span of 80 years). However, it needs to point out that in 2012 yields on long term (20 years), Iranian government bonds ranged between 2 and 2.5%, implying that our estimates may be on the conservative aspect. Although selecting the appropriate discount rate has been a controversial subject in environmental economics. As David Pearce pointed out, there is no magic formula to determine the discount rate, and depending on the kind of criteria, one determine this, i.e., the opportunity cost of capital, or the borrowing cost of capital, or the social time preference rate. Using discount rates of 3–6% in real terms have been suggested for assessing irrigation and forestry projects (Pearce 1992; 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 IRR 2786.705 per m^3 of water stored.

In terms of annuity this works to IRR 136.1832 per m^3 of water stored per annum. Thus the annual economic value of the water conservancy function of the MFR is 973,812,348 m^3 × IRR 136.1832, i.e., IRR 131.587 billion or US$ 1.375 billion (1 US$ = IRR 24700 in 2012).

Soil protection

Forests play a protecting role in arresting soil erosion. Trees anchor the soil with their roots, hence their destruction causes widespread erosion and damage through loss of top soil and nutrients, decrease in land and crop productivity, siltation of rivers, streams, and dams. To estimate the soil protection function of forest ecosystems, one approach is to estimate the extent of loss of soil nutrients due to soil erosion and then employing the replacement cost approach to evaluate the soil protection function. Such an approach has been applied to evaluate the soil protection function of the Chilean temperate forests (Nahuelhual *et al.* 2007). However, this needs field level information on nutrient composition of forest soils which is not readily available, or relying on benefit transfer approach and employing such data from a similar forest site. Another approach is to employ the hedonic pricing method, along with to investigate the impact of loss of soil quality/soil nutrients on the unit value of forest land, then employing this value to estimate the soil protection function. Here again such data are not easily available. A third approach is to use the opportunity cost approach and estimate the economic loss coming from soil erosion. Xue & Tisdell (2001) have employed this method to evaluate the soil conservation function of the Changbaishan mountain biosphere reserve in Northeast China. However, some have reservations about this approach, since it needs pivotal assumptions regarding soil loss and soil thickness to calculate the avoided loss of productive forest land area. It is also discussed that the forest land itself does not vanish due to soil erosion but just shifts from an undisturbed to a degraded state. However, calculating the avoided loss of productive forest land area will assist high point the economic costs of soil erosion and the need for avoiding unsustainable forest practices and usages. Although there are some papers which use the hedonic pricing method, these only assess the value of environmental and other factors on urban property prices (Hidano 2002; Gao & Asami 2007).

Though a few studies in the US, Canada, and Europe have tried to study the parameters influencing forest land prices, they have not assessed the role of soil quality or productivity on property prices, however in a survey in the US, a positive association was observed between soil productivity and farm land prices on the urban fringe near Chicago (Chicoine 1981).

A reduction in forest soil quality will impact on some parameters such as trees growth and biomass. So that, in a study in the US, parameters like quality of land and tree cover led to a maximum 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 IRR 5459.8 per ha in 2009 (Ministry of Jihad-e-Agriculture 2012). Hence, by employing the above parameter, the unit value of forest land in the study area is assumed to be decreased by 8.5% × IRR 5459.8 per ha, i.e., IRR 461.325 per ha due to loss of soil quality. This value multiplied by the forest area, i.e., IRR 461.325 × 62,302.85 ha presents the annual economic value of the soil protection function on the MFR arising to IRR 28.980 million or US$ 312,295.973. 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. In a study it was indicated that the erosion difference between woody and non-woody lands to be 30 mm per annum on average (Xue & Tisdell 2001). The total amount of soil loss can then be estimated by multiplying this parameter with the total forest area. Thus the total amount of soil loss in the reserve is 32 (mm per annum) × 62,302.85 ha = 19,126,583 m^3 per annum. Loss of soil adversely affects the productivity of all natural ecosystems. For example, the productivity losses arising from soil erosion in the US is estimated at over US$ 36.7 billion each year. Eroding top soils compose almost three times more nutrients than that left in the residual soils. The avoided loss of productive forest land area due to soil erosion needs to be calculated. By applying this parameter, the estimated loss of productive forest land area due to soil erosion is the total amount of soil loss separated by the average soil thickness, i.e., 19,126,583 (m^3 $annum^{-1}$)/2.15 (m) = 8,821,463.22 m^2, i.e., 869.84 ha per annum. 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, the opportunity cost approach was applied. So that, the average income from forestry households in Iran (IRR 3250.9 per ha–average for 2010–12) was employed. Thus, the estimated value of the avoided loss of productive forest land area due to soil erosion is 869.84 (ha per annum) × 3250.9 (IRR per ha) = IRR 2,983,457.78 per annum or US$ 32,261.5 per annum. Thus the annual economic value of the soil protection function in MFR is about US$ 0.32 million or in the alternate case, US$ 0.045 million.

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 is released into the atmosphere as CO_2, adding to greenhouse gas emissions. Therefore, afforestation and decreasing deforestation is a significant strategy for combating global warming. Photosynthesis equation production of every 1 g dry organic matter can fix 1.63 g CO_2. To estimate the carbon fixed in forests, most researchers believe on the meta-analysis 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.

To calculate the amount of carbon fixed in the above ground 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 metric ton (mT) (Table 2).

To evaluate this, one could apply the carbon tax or the alternate cost of afforestation or the social cost of carbon. So that, two alternate approaches are used viz., 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.

Though Iran has not introduced carbon taxes or emissions trading, a study of six major economies including Iran by the UK-based Vivid Economics commissioned by Australia's Climate Institute which investigated the direct impact of carbon pricing plans on the power generation sector and of indirect measures such as clean energy incentives, pointed out a carbon price of US$ 3.10 for Iran in purchasing power parity terms. The World Bank recently rewarded a price of US$ 4/t in carbon credits (tCER) for Africa's first big CDM forest carbon project in Ethiopia.

Calculating the social cost of carbon indicates major variations across studies with an average value of US$ 43/tC. Frankhauser (1994) pointed out the marginal social damage costs across different studies to be in the range of US$ 6–45/tC with an average of US$ 20/tC. However, marginal costs should have increased significantly since 1994, along with carbon flows and atmospheric carbon stocks. A recent study proposed marginal costs in the US$ 55–250/t range (Johnson & Hope 2012).

Pearce (2001) suggested the wide range of carbon prices and observed that employing high prices may overestimate the carbon sink services of forests. Hence, his study inserted a price of US$ 10/tC. We used US$ 4 and alternatively US$ 20 to evaluate the carbon fixed by the MFR. So, the economic value of the carbon fixed by the forest reserve annually was about US$ 408,978.7692 or in the alternate case US$ 2,044,893.846. Our above estimate, nevertheless, has not taken into account the carbon in the ground biomass or soil. According to some studies, old-growth forests accumulate important amounts in the soils (Zhou *et al.* 2006; Luyssaert *et al.* 2008). Because of lack of data and difficulties in calculating the soil carbon accumulated in the forest soil, we did not measure it. To this extent, our estimate of the carbon fixed in the MFR may be considered as a lower bound value. We may, however, mention that the National Greenhouse Gas Inventory Report (NGGIR) for 2010 in Iran has estimated the average carbon stocks for forest soils before conversion in Iran at 83.32 tC ha^{-1} in 2010. We are aware that carbon will be sequestered even in alternate landscapes. Therefore, 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 has estimated the biomass stocks and soil carbon stocks for forests and alternate land uses. So that, the biomass stocks for forest lands (before conversion) in 2012 for Iran was calculated at 144.19 t of dry matter per ha (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 was estimated at 65.68 tC ha^{-1} and for croplands at 16.35 tC ha^{-1}. Thus, the additional carbon stored in forests compared to croplands is 65.68 –16.35 tC ha^{-1} = 56.29 tC ha^{-1}. Using the two aforementioned prices (i.e. US$ 5 and US$ 20) to evaluate carbon, this additional carbon stored in the above ground biomass of forests is US$ 210.5 ha^{-1} and in the alternate case US$ 1110.6 ha^{-1}.

The NGGIR estimated the soil carbon stocks in forest lands in 2012 to be 86.25 tC ha^{-1}, and in croplands to be 76.45 tC ha^{-1}, i.e. 7.85 tC ha^{-1} higher in forest lands as compared to croplands. Using the above two alternate prices for evaluating carbon sequestered, the additional value of carbon stored in forest soils is US$ 32.24 ha^{-1}, or in the alternate case US$ 166.5 ha^{-1}. Thus, the added value of carbon stored in the ground biomass and soils as compared to croplands is US$ 235.3 ha^{-1} or in the alternate case US$ 1195.9 ha^{-1}.

Table 2. Estimated amount of carbon fixed in MFR, Iran.

Tree species	Above ground biomass volume m^3 ha^{-1} annum^{-1}	Biomass expansion factor (BEF)	Wood density (D) t-dm m^{-3}	Root to shoot density (R)	Carbon fraction (CF)	Forest area (ha)	Total carbon fixed(in tons perineum)
1. Maple	0.0453	1.22	0.346	0.21	0.4	4664.78	55.1933
2. Hornbeam	0.0453	1.46	0.484	0.46	0.4	1239.81	23.7244
3. Alder	0.0453	1.46	0.483	0.49	0.4	3529.27	69.2268
4. Beech	3.8958	1.26	0.528	0.24	0.4	38,734	72,456.69
5. White Oak	3. 8958	1.58	0.678	0.24	0.4	628.5	1236.63
6. Other species	3. 8958	1.58	0.683	0.24	0.4	14693.46	28,553.22
Total							114,253.687

Nutrient cycling

Forest provide other important service, viz., nutrient cycling. Trees absorb mineral nutrients from the soil as during growth and accumulate these in their body (Xue & Tisdell 2001). As seasons change, some gathered nutrients will return to the soil in withered branches and leaves, while the rest are stored in the stem and roots. Prior to the advent of chemical fertilizers, forest biomass and later marine resources were the main source of fertilizers to augment rice yields in feudal Japan (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. In a study in China, NPK values of 0.155 t and 0.051 t ha^{-1} $annum^{-1}$ were measured for needle and broad leaved forest species respectively (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} $annum^{-1}$ for needle leaved and broad leaved forests (Xue *et al.* 2001). Using these parameters and the biomass productivity, the nutrients (NPK) accumulated in MFR is about 3426.3362 t per annum (Table 3). To estimate the economic value of the nutrients accumulated in two valuation norms are used, viz., the price of green fertilizers (leaf manure), and in the alternate case, that of mixed fertilizers (IRR 171,138 per ton in 2012). However, a study in a forest region in India revealed that the local price of leaf manure to be Rupee (Rs). About 40 per ton in 1988 which worked to about 1.905% of price of mixed fertilizer (Rs. 2100/t) (Nadkarni 1989). Using this parameter, the price of leaf manure for Iran is estimated to be 1.91% × IRR 171,138 /t, i.e., IRR 2092.305 per ton in 2012. Using this price, the economic value of nutrient cycling in the forest reserve is IRR 6.877 million or US$ 0.069 million per annum, and if we insert the price of mixed fertilizers, this value will be IRR 581.861 million or US$ 6.220 million per annum. However, the above estimate accounts for only a part of the nutrients accumulated in the forest. Some of the nutrients in the above ground biomass will also filter to the soil through litter fall, 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.

As mentioned earlier, while broadleaved species are predominant in natural forests in Iran, needle leaved species are predominant in planted forests. Using the NPK values for different species presented in Table 3, and the prices of leaf manure and chemical fertilizers aforementioned, the additional value of nutrients accumulated in MFR is US$ 0.59/ha, and in the alternate case US$ 48.65/ha.

Table 3. Estimated quality of nutrient (npk) accumulated in mfr, Iran.

Tree species	Above ground biomass t/ha/annum	Forest area (ha)	Total above ground biomass t/annum	NPK t/ha/annum	Total NPK t/annum
1. Maple	0.0324	4795.78	114.30	0.01256	1.3762
2. Hornbeam	0.0531	1233.61	51.44	0.01256	0.6202
3. Alder	0.0542	3463.28	129.59	0.01256	1.6283
4. Beech	3.7695	38,364	164,248	0.01256	2376.5063
5. White Oak	3.9352	663.5	2682.29	0.01256	41.5693
6. Other species	3.9163	14,923.4	57,384	0.01256	936.2783
Total nutrients accumulated					3426.3362

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 their purity and medicinal value. New York City, for instance, took advantage of this role of forests to maintain supply of high quality water for its inhabitants by restoring the Catskill watershed catchment that sustains the city water supply rather than invest in a water treatment plant costing US$ 8 billion (Ninan 2011). The soil and water conservation, and water purification are inter-related, but these are the 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 investigated the annual effective water supply by water utilities for domestic purpose and in an alternate case, the quantity employed for domestic and industrial purposes in 2012, which was 198 million m^3 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 such data are not willingly available. Sedimentation will adversely affect water quality, reduce the effective storage capacity and life of reservoirs as well as corrode hydro-power turbines. However, deforestation or natural calamities such as landslides can make these expectations go away. 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 will be 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 mentioned before, the estimated annual cost of storing 1 m^3 of water in this dam is IRR 145.15. Of this 5.2%, i.e., IRR 7.15 per 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 in the MFR found to be 198 million m^3 × IRR 7.15/m^3 = IRR 1,426,850,000 or US$ 16.104 million or in the alternate case, 617 million m3 × IRR 7.15/m^3 = IRR 4,410,700,000 or US$ 45.845 million.

Air purification

Trees support absorb and decompose damaging gases such as sulfur dioxide (SO_2), nitrous dioxide (NO_2) and other harmful gases through special organs and physiological performance. Forests, thus support 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 to be 88.65 kg and 215.6 kg per ha, 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 per ha per annum for SO_2, NO_2 and total suspended particulates in recreational areas of the city (Jim & Chen 2008). A study on dry deposition rates of SO_2 in a Japanese cypress forest in Shiga prefecture suggested annual deposition rates of 3.1 to 3.5 kg per ha (Obote *et al.* 2002). In another study, the gas sink services of field and mountainous areas in Japan presented annual absorption rates of SO_2 and NO_2 to be 11.1 and 16.2 kg per ha respectively (Yoshida 2001). These parameters (i.e. 11.1 and 16.2 kg per ha) multiplied with the total forest area and then with the engineering cost of controlling SO_2 and NO_2 (IRR 272,000 and IRR 1,258,000 per ton respectively) gives the economic value of the air purification functions in MFR. These annual values are IRR 179.5 million (US$ 1.9 million) and IRR 1201.12 million (US$ 12.65 million) for SO_2 and NO_2 respectively or a total value of US$ 15.1 million per annum. 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 compared to paddy lands, we used the annual absorption rates of SO_2 and NO_2 for forests and paddy lands in Iran (Yoshida 2001). This was 11.1 and 16.2 kg per ha for forests, while 10.09 and 13.89 kg per ha for paddy lands respectively. Using the above parameters and the engineering costs for controlling SO_2 and NO_2, the annual values of these gases absorbed by forests was IRR 2914.6/ha (or US$ 31.12/ha) and IRR 18,958/ha (or US$ 202.34/ha) respectively. For paddy lands, these values were IRR 2634.36/ha (US$ 28.04/ha) and IRR 17,215.1/ha (US$ 189.65/ha) 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 US$ 21.5 per ha.

Recreation

Forests also provide recreation benefits. The MFR covering some areas, attract several tourists and visitors because of its scenic beauty, mountains, marshlands, and lakes. During 2013–15 the park attracted an average of 0.55 million visitors per annum. Although there are no entrance fees to the parks, visitors incur expenditure for travel, board and lodging besides their time. However, data on these are not available. To estimate the economic value of the recreational benefits, we used two alternate prices. In one case we multiplied the number of visitors to the park by the individual willingness to pay for conservation of Oku Aizu (North of Tokyo, Japan) forest ecosystem demonstrated in a recent survey which was ¥ 3256 per person per annum assuming status quo conservation scenario, i.e., core zone constituting 9.4% and buffer zone 91.8% of the forest reserve, and a green corridor around the forest reserve; and in the alternate case ¥ 6532 per person per annum assuming full protection scenario, i.e., the entire forest is nominated as core zone with no buffer zone (Yoshida 2001). The logit model was used for measuring individuals WTP. Estimation parameters of the model are based on the method of maximum likelihood (ML). On this basis, the annual economic value of the recreational benefits in MFR is IRR 1.191 billion or US$ 10.62 million and in the alternate case IRR 2.63 billion or US$ 26.4 million. Department of Environment, 2002 perhaps the first to calculate the ecosystem service values of forests in Iran, cited in a recent TEEB (White *et al.* 2011), investigated tourist expenditures as the economic value of the recreational benefits of the forests. In conventional economic theory people spending money on an activity until the marginal benefit equals marginal cost. At the margin then cost equals benefit. However, several researches (e.g. Pearce & Moran 1994) indicated that the consumer surpluses of visitors to national parks and recreation sites are significant, hence what consumers or visitors are willing to pay in order to enjoy or visit a recreational site rather than what they actually paid, ought to be reckoned while estimating the economic benefits of recreation.

Total economic value of ecosystem services

A summary of estimating the total economic value in 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 presented in the Table includes the lower of the two sets of the estimated values of ecosystem services, while estimate 2 includes the higher of the two sets of values so as to demonstrate the range of the estimated values. As shown in Table 4, this annual value of the seven ecosystem services evaluated ranges US$ 1.432 to 1.490 billion or about US$ 16,863 to 18,321 per ha per annum. 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 & de Groot (2012) reported, 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 regulatory mechanism. Dynamic factors and environmental catastrophes will also affect the provision and values of ecosystem services.

CONCLUSION

The benefits provided by the MFR are significant. Even without considering habitat, biodiversity and cultural values, flood protection, pollination and NTFP benefits and so on, the total annual economic value of the ecosystem services estimated by this forest reserve are worth millions of US dollars. 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, the total ecosystem service benefits of conserving forests rather than the added value or the difference in the benefits of conserving forests in comparison with its alternate uses. Such an analysis would have provided the economic justification for conserving forests vis-a-vis its 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 its alternate uses. So that, Beukering *et al.* (2003) in a study on Leuser national park in Indonesia reported the benefits of the park under three alternative scenarios – deforestation, conservation and selective use. Their results (accumulated TEV at 3% discount rate over 30 years) suggested that the conservation option was most beneficial (US$ 9538 million) compared to selective use (US$ 9100 million), and deforestation (US$ 6958 million). Using available evidences, our study showed that the quality of water retained, carbon sequestered, nutrients accumulated and air pollutants absorbed by forests is higher than in alternate land uses.

This lends support to the economic case for conserving forests.

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Table 4. Summary of the total economic value of ecosystem services provided in MFR, Iran.

Ecosystem service	Annual value US $ million (2015)	
	Estimate 1[a]	**Estimate 2[b]**
1. Water conservation	1384.634	1382.453
2.Soil protection	0.063	0.769
3.Carbon fixation	0.672	3.638
4.Nutrient cycling	0.104	9.132
5.Water purification	15.168	44.372
6.Air pollutant absorption	11.759	14.869
7.Recreation benefits	12.853	26.836
Total	1432.739	1490.825

[a] Estimate 1: Water conservation – volume of water conserved by the forest reserve valued at the economic cost of storing 1 m^3 of water; 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; Carbon fixation – Annual amount of carbon fixed valued at carbon price; Nutrient cycling – NPK accumulated valued at unit price of leaf manure i.e., ratio of price of leaf manure to price of mixed fertilizer × price of mixed fertilizers; Water purification – volume of water for domestic purpose valued at the unit cost of managing sediments in dams (i.e., IRR m^{-3}); Air pollution (SO_2 and NO_2) absorption – Amount of air pollutant absorbed valued at the engineering cost of controlling SO_2 and NO_2; Recreation benefits – Number of annual visitors to MFR valued at the individual Willingness to Pay (WTP) for conservation of MFR ecosystem assuming 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 alternate methods or prices. Estimate 1 includes the lower of the two sets of the estimated values of ecosystem services.

[b] Estimate 2: Same as above except the following: Soil protection – forest area valued at the amount of decline in the unit value of forest land (in IRR ha^{-1}) due to loss of soil quality/soil nutrients; 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; Nutrient cycling - NPK accumulated valued at unit price of mixed fertilizers; Water purification – volume of water used for domestic and industrial purposes valued at the unit cost of managing sediments in dams (IRR m^{-3}); and Recreation benefits – Number of annual visitors to MFR valued at the individual willingness to pay for conservation of MFR assuming full protection scenario, i.e., full 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 alternate methods or prices. Estimate 2 includes the higher of the two sets of the estimated values of ecosystem services.

Noteworthy, 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 Indian forest cover. This compensation payment was specified on the basis of an economic valuation study of Indian forests. Noteworthy, this compensation is determined based on the 'total benefits' or 'total value' of the forests, but not the 'added value' which is mentioned in a TEEB (White *et al.* 2011). From the forest management point of view, the MFR studies have had results. First of all, it proved that the people in Iran were aware of the MFR and its importance. Second, it was clear that a high willingness to pay in terms of both cash and kind exists in Iran for contributing towards the upkeep and improvement of MFR. Notwithstanding the aforementioned limitations, in the present study, we found 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 consider it while making decisions, which may have some influences on natural resources and ecosystems.

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چکیده

جنگل‌ها نقش مهمی در رفاه انسان دارند بطوری که توجه اقتصاددانان بیشتر بر ارزش بازار محصولات جنگلی تمرکز دارد. در حال حاضر این روند، در حال تغییر است بطوری که ارزش‌های غیر بازاری جنگل‌ها به طور فزاینده‌ای مورد توجه و اندازه‌گیری قرار گرفته‌اند. به تازگی ارزش اکوسیستم جنگل توسط اقتصاددانان منابع طبیعی مورد مطالعه قرار گرفته است و نقش آن در رفاه بشر تضمین شده است. این مقاله نشان می‌دهد که ارزش استفاده سالانه از خدمات اکوسیستم مانند حفاظت از آب، حفاظت خاک، تثبیت کربن، جذب مواد مغذی، تصفیه آب، جذب آلودگی هوا و گردشگری ارائه شده توسط جنگل‌ها به ارزش میلیون‌ها دلار، در هر هکتار، بیشتر از قبل شناخته شده است. این ارزش برای ذخایر جنگلی مازندران در حدود ۱۴/۲ تا ۱۴/۸- میلیون دلار یا در حدود ۶۷۸۵/۶ تا ۶۶۷۶/۹ دلار در هر هکتار بوده است. اگر این نتایج در نظر گرفته شود، دولت‌ها و جوامع در مقابل معضل حفاظت از محیط زیست می‌توانند در اتخاذ تصمیمات و سیاست‌ها درک بیشتری کسب کنند که به حفاظت از جنگل‌ها و خدمات اکوسیستمی منجر گردد. تحقق این مزایای نامحسوس قابل توجه، در تصمیم گیری‌های آگاهانه و سیاست‌هایی که به حفظ اکوسیستم های جنگلی و همچنین ارتقاء سلامت بشری و توسعه پایدار کمک می‌کند.

*مولف مسئول