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Modeling of ecosystem services informs spatial planning in lands adjacent to the Sarvelat and Javaherdasht protected area in northern Iran

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ABSTRACT

Dynamic models of ecosystem services supply and scenario analysis of changes in multiple services are being increasingly used to support land use planning and decision making. This approach reduces potential and real conflicts among various stakeholders potentially creating win–win solutions for all. It is particularly applicable in areas where insufficient land for agriculture and settlements is resulting in high rates of conversion of natural forest and grasslands. We quantified and mapped multiple ecosystem services, including habitat provision as a proxy for biodiversity, carbon storage and sequestration, and water balance and supply in the Sarvelat and Javaherdasht region of the globally-significant Hyrcanian (Caspian) forests in northern Iran using the Integrated Valuation of Ecosystem Services and Tradeoffs tool. This region is experiencing a rapidly increasing rate of forest conversion and as a result, the protected area located within the study landscape is threatened by human encroachment. Plausible future landscapes were modeled under three scenarios: (i) business as usual; (ii) protection-based zoning which reflects an expansion of the protected area boundary to prevent land use changes; and (iii) collaborative zoning through redefining the protection boundary simultaneously with an adjustment to meet local stakeholders' objective of expansion of anthropogenic cover. The results showed that the collaborative zoning scenario would best contribute to effective policy because it presents a more rational spatial configuration of the landscape maintaining the provision of ecosystem services. This scenario may lead to reduced environmental impacts while achieving less conflict between the government and local communities. These results will help to inform and shape natural resource management policies in Iran and is applicable elsewhere in the world.

1. Introduction

Ecosystems and their associated biological diversity provide a wide range of ecosystem services (ES) which benefit human well-being (Bastian et al., 2013; MEA, 2005). Internationally, the importance of maintaining ES through the conservation of biodiversity is recognized through Aichi Target 11, which falls under Goal C of the Convention on Biological Diversity (CBD) Strategic Plan for 2011–2020. This commits all parties to conserve areas of particular importance for biodiversity through well-connected systems of protected areas to enhance the benefits to communities from their ES (Woodley et al., 2012). Biodiversity underpins the continuous provision of ES which is essential for human survival and well-being (Balvanera et al., 2012) and the success of the economy

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and social welfare. The Millennium Ecosystem Assessment (MEA, 2005), classifies ES as *provisioning* (e.g. food production), *regulating* (e.g. carbon sequestration), *cultural* (e.g. recreation) services that directly affect people, and *supporting* services (e.g. provisioning of habitat and primary production) which are vital for maintaining the other services.

Despite their obvious importance for quality of life, ES are declining in many ecosystems due to human encroachment (MEA, 2005). While population growth that increased the demand for ES, the capacity to supply such services is decreasing due to extensive human alteration of natural ecosystems in recent decades (DeFries et al., 2004; Foley et al., 2011). There are numerous factors which affect the supply-demand interaction of ES within a complicated social-ecological system (Nassl and Löffler, 2015) and hence, there is an increasing focus on spatial modeling of ES and drivers of change to help develop land-use policies and support more effective decision-making (Bélair et al., 2010; Paudyal et al., 2016; Power, 2010).

Human interventions which result in the loss of ES occur mainly through changing land use/land cover (Bennett, 2005; Bennett and Balvanera, 2007; Bhatta et al., 2015; Zarandian et al., 2016) here abbreviated to land cover. For example, management decisions that are taken to increase food production through agricultural development, or expansion of settlements through forest clearing, may negatively impact ES such as climate regulation and habitat availability (Baral et al., 2014a). Therefore, after assessing the current state of ES supply in a given area, prediction of the impacts of changes in ES supply, based on future plausible scenarios, can help decision-making and reduce risks (Raudsepp-Hearne et al., 2010; Swetnam et al., 2011; Wollenberg et al., 2000).

With the availability of new predictive tools, it is possible to predict the impact of changes in land use policies and different management regimes and decisions on ES supply. ES are incorporated in land use planning and conservation investment through robust quantification of the stocks and flows of such services and placing economic values on them (Kareiva et al., 2007; Palomo et al., 2013; Tardieu et al., 2013; Wittmer and Gundimeda, 2012). At a broader environmental policy level, planners need to understand where, when, and what ES are supplied by a specific landscape so that the effects of policy options and decisions can be monitored (Baral et al., 2014a; Bhatta et al., 2016; Crossman et al., 2013; García-Nieto et al., 2013; Mubareka et al., 2013). One of the major challenges is to develop appropriate methods for ES mapping and understand how regulating and supporting services are affected by human activities in the landscape as there are inconsistencies between existing ES quantification and mapping methods, hindering their application in planning and management processes (Baral and Holmgren, 2015; Crossman et al., 2013; Paudyal et al., 2016). In addressing these challenges, standard dynamic ES models have been developed to facilitate mapping of ES supply, providing powerful tools for processing spatially and temporally complex data (Burkhard et al., 2012a,b; Crossman et al., 2012; Martínez-Harms and Balvanera, 2012) and analysis of tradeoffs between multiple ES under different scenarios (Boumans et al., 2002; Nelson et al., 2009). Scenario modeling and analysis facilitates assessments in complex systems such as ecosystems and has become an important part of integrated environmental assessments, including those which have been carried out by the Intergovernmental science-policy platform on biodiversity and ecosystem services (IPBES) and the Millennium Ecosystem Assessment (Robinson et al., 2016).

Many studies have been carried out on the effects of ecosystem conversion (e.g. forests, wetlands and rangelands) on ES supply such as the consequences of land use change for carbon sinks (Eaton and Lawrence, 2009), primary production (Portela and Rademacher, 2001) and water flows and quality (Uriarte et al., 2011). However, in most developing countries, such as Iran, environmental studies using an ES approach are in their infancy, and as yet there has been no study conducted with an explicit focus on multiple ES modeling. This research is the first practical step in the application of existing models in a quantitative ES assessment in the Iranian Sarvelat and Javaherdasht forested landscape, including its protected area, where native forest land conversion for housing and farm development has accelerated in the last three decades. Elsewhere, we have assessed the status and trends of key ES in this region using a rapid, qualitative and participatory approach, including interviews with local households and experts in combination with an assessment of remote sensing data on land cover to identify and map priority ES in GIS (Zarandian et al., 2016). The results showed that, although food production and recreation have greatly increased in recent decades, other services, in particular, timber production, habitat provision, and water purification and supply, gradually are being lost (Zarandian et al., 2016). Since the current process of land conversion has resulted in increased conflict between different stakeholders, including conservation organizations and landowners, here in this current study, we present a possible win–win solution to reduce conflicts and seek a compromise between the land cover changes and nature conservation based on an ES approach.

Our specific aim was to predict plausible future land use scenarios through mapping the spatial distribution and quantification of habitat provision, carbon sequestration and water balance ES in the current landscape. Through the development of these future land use scenarios we aimed to inform policy makers on how they may best formulate effective land use policy while resolving potential stakeholder conflicts.

2. Materials and methods

2.1. Study area

The Sarvelat and Javaherdasht forested landscape covers an area of 55,840 ha and is located between 36°48′- 37°03′ N latitude and 50°22′–50°45′ E longitude, lying within the boundaries of two provinces, Gilan and Mazandaran, in the northern part of Iran (Fig. 1). Iran, declared 21,254 ha of this area as a protected area in 1999, as this area plays an important ecological role in the provision of ES such as water balance and climate regulation (Zarandian et al., 2016).

This region is mountainous with an altitudinal range of zero to 3550 m above sea level. The lowlands have a humid temperate climate with an average annual temperature of 14 °C and average annual precipitation of 1150 mm. The Hyrcanian (Caspian) mixed forest of northern Iran and southern Azerbaijan is a deciduous broad-leaved forest classified as ecoregion number 78 in WWF's Global 200 Ecoregions (Olson and Dinerstein, 1998).The area contains remnants from the Tertiary period and has around 150 endemic species of trees and shrubs, and 60 mammal, 340 bird, 67 fish, 29 reptiles, and 9 amphibian species. The landscape lies along an important bird migratory route between Russia and Africa and is listed as an important bird area (IBA) (Caspian Hyrcanian Forests Project, 2015). It has been listed by Iran as a future site for nomination as a World Heritage site (UNESCO, 2015). About 86% is covered with forest most of which is located at an altitude of 400–2000 m. Other land uses are orchards/gardens (mainly citrus groves), farmlands (rice) and human settlements which, respectively, account for approximately 1%, 4% and 3% of all land cover and are located in the lowlands. Approximately 4% of the landscape is bare rock, mostly located at altitudes above 2,800 m.

Since the establishment of a protected area in the southern part of the landscape, and given that this area is bordered on the north by the Caspian Sea, there is limited flat land available for