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Mapping regulating services in Marrakesh Safi region - Morocco

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ABSTRACT

Mapping ecosystem services (ES) has become an important tool to study nature's contributions to people (NCP) spatially and to manage ecosystems sustainably. However, few of these studies have been carried out in Africa and even fewer in drylands. This is not surprising, as drylands in general have not received much attention in the field of ecosystem services due to the perception that they do not provide much due to their low levels of productivity. In addition, not much data is available to map ecosystem services in Africa. In this study, we map regulating services of the Marrakesh Safi region in Morocco. First, a land cover map was developed based on existing information. This land cover map was thereafter used to map and model three regulating service categories in the region namely, carbon sequestration, microclimate regulation, and hydrological services (water regulation and water quantity) using six indicators. Our results show that agricultural land, which occupies the largest percentage area, also sequestered the most carbon in the study area. Forests sequestered about 16% carbon despite occurring in only 14% of the area and are the most efficient in sequestering carbon when considering carbon sequestered per hectare per year. The ecosystem type with the highest potential to supply water regulation services was *Quercus ilex* with about 200 m^3/ha. The study shows that the hotspots areas are located in the southeast parts of the study area where the *Quercus ilex* is mostly found. Contrary to the belief that most arid systems are not productive and therefore do not provide many ecosystem services, our spatial outputs showed that the area around Marrakesh in Morocco, despite being arid provides many regulating services including water and microclimate regulation.

1. Introduction

Global initiatives geared towards the sustainable use of ecosystems to support human wellbeing require that ecosystem services (ES), which are the benefits humans derive from nature be made spatially explicit. Examples where such spatial representation would be useful include in the recently endorsed Sustainable Development Goals (SDGs) of the 2030 Agenda for Sustainable Development, Convention on Biodiversity (CBD), United Nations Convention to Combat Desertification (UNCCD) and Intergovernmental Panel for Biodiversity and Ecosystem Services (IPBES). Several mapping studies have been initiated to support these initiatives (Burkhard et al., 2013; Crossman et al., 2013; Egoh et al., 2008; Maes et al., 2013; Willemen et al., 2017). According to Hauck et al. (2013a) maps are a powerful communication tool that can be used to improve the targeting of policy measures, by serving as support for legal documents, and in some cases may create agreements between stakeholders and authorities. In addition, maps can be used in planning and management processes in order to better understand the values or trade-offs that arise from land cover and land use changes (e.g. Egoh et al., 2008, 2011; O'Farrell et al., 2011). The special issue on the mapping and assessment of ecosystem services in the journal of Ecosystem Services aimed at responding to the needs of developing methods for mapping and modeling ES (Willemen et al., 2015). Several other studies also confirm that decisions about natural resources would be more effective, efficient and defensible when based on spatially explicit quantification of ecosystem services (Haines-Young et al., 2012; Nelson et al., 2009; Raudsepp-Hearne et al., 2010).

While there has been, an overflow of mapping approaches developed and mapping of ecosystem service studies around the world, Africa appears to be left behind both in terms of marine and terrestrial ecosystem service mapping (Costanza and Kubiszewski, 2012; Egoh et al., 2012a; Liquete et al., 2013). In many areas of the world, including Africa, drylands have particularly been neglected in this field of study, because of low productivity and perceived limited ecosystem services. This perception is not necessarily true as many drylands have

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exotic species and ecosystems that provide unique services (Egoh et al., 2016). Indeed, these regions have higher demand for ecosystem services than most humid areas. Arid and semiarid regions of Africa are particularly limited in spatial and temporal information partly due to lack of resources. Another factor that has caused the lag in spatial modeling of ES in Africa is this limitation of data availability. While data exist for most provisioning services, information needed to map regulatory services is limited and often reduced to land cover (Egoh et al., 2012a). For the arid and semiarid regions, water regulation is central for agricultural production as well as sustainable water supply in streams. Similarly, micro-climate is of great importance as temperatures are projected to rise with a changing climate which may add stress on agricultural production and water use.

One of the most important data layers required for ES mapping is land cover (Egoh et al., 2012a). Indeed, Burkhard et al. (2009) propose a new method for mapping ecosystem services based on land cover integrity using expert knowledge. However, most existing land cover maps are coarse scale of broad categories (e.g. forest, urban, grassland) of cover without necessary specification of different vegetation types. More detailed information on land cover such as forest types can be useful as different vegetation types play different roles in the ecosystem. Some models used to map ecosystem services such as the Agricultural Catchments Research Unit model (ACRU), require more detail difficult to measure information such as monthly values of the water use coefficient, the fraction of active plant roots in the topsoil zone and the daily rainfall reference evaporation (Warburton et al., 2010). Land cover information in Africa is limited and existing data covers very broad land cover categories. For example, the land cover map produced by Mayaux et al. (2004) has fewer than 30 classes for the whole of Africa with most of North Africa classified as desert. There is therefore a need to create land cover maps at finer local scale to provide more precise ES mapping.

In this study, we developed a local scale land cover map for the region of Marrakesh Safi (Fig. 1), using compilation of available information. The land cover map was thereafter used to model and map three categories of regulating services in the region: 1) carbon sequestration, 2) microclimate regulation (using evapotranspiration, ground temperature, and canopy temperature) and 3) hydrological services: water quantity, and water regulation.

We explicitly differentiate how each vegetation types contribute to the indicators used in measuring the delivering of these three service categories. Finally, we identify hotspots for these services where planning should be carried out to prioritize management. The ES were chosen to reflect on Morocco's strong interest and involvement in climate change, its future impact in the country and how it may affect ecosystem service delivery. This dryland region remains vulnerable to climate fluctuations and may see changes in temperature and rainfall which could have significant implication for the limited productivity of the landscape and consequently on water availability for the millions of people who live in this area (Niang et al., 2014).

Regulating services are one of the most mapped services around the world (Egoh et al., 2012a), particularly in Africa due to the importance of regulating services such as water for food production and infiltration for flood attenuation (Egoh et al., 2012b). However, no study we know of, has mapped regulating services in northern Africa as most of the studies are in southern and eastern Africa. For an arid region, water regulation is crucial for agricultural production, erosion control as well as maintaining the flow of water in streams. Similarly, microclimate regulation is of great importance as temperatures in this region can rise as high as 40 °C in summer. These high temperatures will be exacerbated by climate change making microclimate regulation an important ecosystem service. Planting trees for their shading (shortwave radiation reduction) and evaporative cooling is a simple 'means' in the hand of urban planners to mitigate thermal stress in the climate regions with long and warm summers (Erell et al., 2011; Shashua-Bar et al., 2011) but this service can be provided by natural areas. Tree species can mitigate the soaring of temperature through carbon sequestration and storage but they can also provide microclimate regulation for regions such as Morocco.

2. Study area

The Marrakesh Safi region is one of the twelve regions of Morocco covering about 5% of the total area of Morocco with 39,167km2 (Fig. 1) and a population estimated at 4 million inhabitants (RGPH, 2015). The climate of the region is semi-arid to arid, except for the High Atlas Mountains at an altitude between 1500 m and 2000m where the climate is considered as humid (MI, Monograph of the region, 2015). The annual rainfall in the study area ranges between 800 mm in the mountainous region to 190 mm in the lowlands. Marrakesh Safi is one of Morocco's most important areas in terms of biodiversity (Fennane, 2004; Fennane and Ibn Tattou, 1994). It houses a large number of endemic fauna and flora including close to 423 endemic plants (Fennane, 2004), many of them are on the IUCN "International Union for Conservation of Nature" red list (Baillie et al., 2004). Toubkal National Park, the largest national park in Morocco, is located in the South of Marrakesh Safi and considered as an important biodiversity hotspot and corridor of the Mediterranean basin (Derneği, 2010). The main ecosystems in this region include forest, agro-ecosystem, continental fresh water and marine and coastal ecosystem.

In this study, we focus on the terrestrial ecosystem, which consists mainly of forest and agro-ecosystem. The forest ecosystem covers an area of about 500,000ha, of which about 8% is plantation, found mostly in the High Atlas Mountains in the South of the region (HCEFLCD, 2005). The most important forest types in the study area are: Quercus ilex [*Quercus rotundifofia*] (157,660ha) also known as evergreen oak, Thuja [*Tetraclinis articulata*] (136,960 ha) and Argania [*Argania spinosa*] (132,910 ha) (Table 1). The Agro-ecosystem is considered the most important ecosystems in the region for its agricultural potential in both Bour (rainfed) and irrigated agricultural practices. The agricultural land occupies up to 51% of the region with cereals being the dominant crop.