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# Differential effects of valuation method and ecosystem type on the monetary valuation of dryland ecosystem services: A quantitative analysis

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ABSTRACT

The method of monetary valuation of ecosystem services has been argued to depend on the type of ecosystem under consideration and the choice of valuation method. Still, the impact of these factors has been hardly studied in a quantitative manner. This study aims to analyze the differential effects of ecosystem type and valuation method on the values estimated for ecosystem services, as well as the potential impact of these effects on aggregated values for ecosystem services. Drylands pose a highly relevant case to investigate these impacts, because they are particularly diverse in ecosystem types, the provided ecosystem services and, hence, are also expected to be estimated with various methods. Our analysis is based on a quantitative analysis of monetary estimates for ecosystem services (expressed in Int$/ha/yr) that were compiled in a comprehensive database containing 512 observations from 57 studies located in drylands worldwide. Our results reveal that the estimated values for dryland ecosystem services depended on the type of ecosystem and method under consideration. Several of these differential effects had a significant impact on the aggregated mean values for dryland ecosystem services. Cultivated lands had high mean values for provisioning services, in particular for food provision, but low values for regulating services. In dry forests, biodiversity-related services were estimated high, in contrast to semi-deserts and arid wetlands. Compared with other methods, market pricing estimated low values for climate regulation and high values for biological regulation. When values were aggregated for ecosystem services, market pricing was found to impact the mean value for climate and biological regulation significantly. Our results highlight the importance of explicit consideration of methods and ecosystem types in monetary valuation, which could lead to more accurate approximation of ecosystem service values.



## 1. Introduction

The valuation of ecosystem services is a means to express the (relative) importance of the benefits that people obtain from ecosystems (Daily et al., 2009). Although recently more attention is directed towards non-monetary and integrated valuation approaches (Kelemen et al., 2016) and despite various criticisms on monetary valuation approaches (Bockstael et al., 2000; Kallis et al., 2013; Spangenberg and Settele, 2010; Spash, 2008), the empirical studies on the valuation of ecosystem services are still predominantly concerned with economic or monetary valuation of ecosystem services (de Groot et al., 2012; Liu et al., 2010). Also global databases for ecosystem service values, such as The Economics of Ecosystems and Biodiversity (TEEB, 2010a), which are typically used to value ecosystems and management practices, primarily include monetary value estimates.

Meanwhile, it has been observed that monetary valuation of ecosystem services may depend strongly on the appraisal process (Jacobs et al., 2016; Vatn, 2009). The choice of valuation methods has been claimed to direct the valuation outcome (Martín-López et al., 2014; Spangenberg and Settele, 2010; Vatn, 2009; but for a contrast see Brander et al., 2006), also because valuation methods tend to be used outside their originally intended scope of application (Bateman et al., 2011; Farber et al., 2006). In addition, the type

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of ecosystem that is delivering the ecosystem service in question has been noted to affect the monetary value, as the capacity of ecosystems to deliver services may vary based on the underlying functions and processes (La Notte et al., 2015; Villamagna et al., 2013).

However, only a few studies have investigated whether these factors affect the estimated monetary values for ecosystem services in a quantitative manner. Ghermandi et al. (2010) found that the monetary valuation of ecosystem services in wetlands depended on the type of wetland ecosystem considered, while Quintas-Soriano et al. (2016) found that the monetary valuation of ecosystem services in Spain was affected by the methodological approaches of valuation methods.

Yet, although the impact of these factors on the monetary valuation of ecosystem services has been described extensively, still many studies aggregate monetary values of ecosystem services in order to calculate the total economic value of ecosystems or biomes. A well-known example is the study by Costanza et al. (1997) that aggregated values for different ecosystems to arrive at global estimates for the value of nature. More recent examples are studies that have summed up values delivered by different ecosystems to arrive at a total value for a particular study area (e.g. Brenner et al., 2010), while others have aggregated values for ecosystem services that were estimated with different methods and delivered by diverse ecosystems to come to total values for global biomes (e.g. de Groot et al., 2012) or country-wide assessments (e.g. UK National Ecosystem Assessment, 2011).

The extent to and the conditions under which valuation methods and ecosystems affect the monetary values estimated for ecosystem services, and hence also the total economic values, have not been investigated comprehensively and quantitatively so far (Jacobs et al., 2016). Hence, such a quantitative analysis can give important insights into whether these aspects affect the research outcomes of valuation studies. In particular, since the valuation of ecosystem services may be confounded, when different methods or specific ecosystem types are selected preferentially.

The interdependencies between ecosystem service value estimates and the type of ecosystem on the one hand and valuation method on the other hand may, particularly, play a role in drylands, because they include a diversity of ecosystem types within their biome (i.e. as occurring across arid to sub-humid climates, coinciding with a 0.05–0.65 aridity range; Bastin et al., 2017; Maestre et al., 2012; UNCCD, 1994). These ecosystem types include semi-deserts, grasslands, woodlands and dry forests, but also cultivated lands and (semi-)arid wetlands (from here onwards called arid wetlands; Millennium Ecosystem Assessment, 2005; Shackleton et al., 2008). Though the latter category may seem counterintuitive, a high number of arid wetlands occurs within drylands, particularly in semi-arid and sub-humid climate zones (Williams, 1999). These arid wetlands are often temporary due to seasonal or erratic filling (Scoones, 1991; Walker et al., 1995; Williams, 1999). In addition, drylands are diverse in the ecosystem services they can deliver, on which an estimated third of the global human population depends for their well-being and livelihood (Bagstad et al., 2012; Millennium Ecosystem Assessment, 2005; Reynolds et al., 2007; Shackleton et al., 2008). Hence, drylands are a highly relevant case to investigate the possibly confounding, differential effects of ecosystem types and valuation methods on the value estimates of ecosystem services provided.

Our aim was to carry out a systematic analysis of the differential effects of ecosystem type and valuation method on the monetary value estimates (as expressed in Int$/ha/yr) for dryland ecosystem services, based on a quantitative analysis of monetary value estimates for ecosystem services located in drylands worldwide. With differential effects, here, we mean the different effects of dryland ecosystem types and valuation methods on the estimated values for dryland ecosystem services: estimated values for dryland ecosystem services may differ, when they are provided by different dryland ecosystem types or when they are estimated with different valuation methods. In order to address our study aim, we, firstly, aimed to investigate whether and to what extent the monetary value estimates for particular dryland ecosystem services depended on the dryland ecosystem type under consideration. Secondly, this study aimed to analyze whether and to what extent the monetary value estimates for particular dryland ecosystem services depended on the valuation method applied. Thirdly, this study aimed to evaluate the potential impact of specific ecosystem types and valuation methods on the aggregated mean monetary values for dryland ecosystem services in order to assess potential bias when such values are aggregated.

We expected that ecosystem services provided by different dryland ecosystems would have different monetary value estimates, based on the literature cited above. For example, due to the high capacity of arid wetlands to deliver water-related services (i.e. fresh water provision and water regulation), these may be expected to be valued highly. Also, we expected that different valuation methods would lead to different monetary value estimates for the same dryland ecosystem service, as these methods are based on different valuation approaches and address different value types (Bateman et al., 2011; Farber et al., 2006). For example, as market-based methods are specifically developed for valuation of provisioning services, they are expected to provide better estimates for these services than, for example, revealed preference methods which were primarily developed for valuation of cultural services. Finally, we expected that the above-mentioned, differential effects would affect aggregated value estimates for dryland ecosystem services.

## 2. Methods

### 2.1. Database of dryland ecosystem service values

We compiled monetary value estimates for dryland ecosystem services in a self-compiled database. As a starting point, we used the TEEB valuation database (van der Ploeg and de Groot, 2010), from which we only extracted studies that were located in drylands, i.e. having a degree of aridity between 0.05 and 0.65 (following the definition of drylands by the UNCCD (1994); thus excluding hyper-arid regions having an aridity lower than 0.05). Based on these records, we went back to the original valuation studies to validate the recorded data and, where needed, recode observations into singular ecosystem service value estimates. Next to the studies extracted from the TEEB database, we complemented the database with valuation studies that were collected from an additional literature review of peer-reviewed and grey literature. Observations were only included in the database when they met the following criteria: (1) the study site was located in a dryland (i.e. having a degree of aridity between 0.05 and 0.65), (2) the recorded value estimate was for a singular ecosystem service, (3) the value estimate for an ecosystem service represented a monetary value that could be standardized, and (4) sufficient data characteristics were available on the ecosystem service, ecosystem type and valuation method. As a result, an observation in our dataset represents the monetary value estimate for a dryland ecosystem service (1) for a specific ecosystem service, (2) delivered by a specific dryland ecosystem, and (3) calculated with a specific valuation method. From some valuation studies, single observations of dryland ecosystem service value estimates were collected, while from other studies multiple observations for dryland ecosystem services value estimates were collected, either for

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