# Multi-Criteria Decision Analysis to identify dryland ecosystem service trade-offs under different rangeland land uses

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## ARTICLE INFO

## ABSTRACT

Land degradation undermines ecosystem service provision, limiting economic returns from semi-arid rangelands. We apply a Multi-Criteria Decision Analysis (MCDA) to assess the value of ecosystem services, using monetary and non-monetary techniques in semi-arid rangelands in Kgalagadi District, southern Botswana. In doing so, we provide an empirical understanding of the linkages between policy, land use and the provision of ecosystem services based on the perspectives of local stakeholders identified through interviews and a workshop consultation. Findings suggest communal grazing provides the widest range of monetary and non-monetary values linked to ecosystem service delivery. Current economic incentives and policy initiatives supporting the livestock sector, linked to fencing and borehole drilling, create perverse incentives that over-emphasise commercial food production at the expense of other services. We identify a need for policy reforms to support livelihood diversification through the provision of a wider range of ecosystem services, and for further research to explore market opportunities for veld products and carbon trading. We show that MCDA offers a useful holistic assessment framework that could be applied more widely to semi-arid rangelands globally.

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## 1. Introduction

Land degradation is driven by a variety of socio-economic, political and environmental factors, and undermines a range of ecosystem services (ES) for billions of people who depend on the natural resource base for their livelihoods and subsistence (Foley et al., 2005). The United Nations Convention to Combat Desertification (UNCCD) provides an important international policy framework for countries to tackle land degradation. At the national level, parties to the UNCCD develop National Action Programmes (NAPs) to outline the national status of land degradation, and provide a Sustainable Land Management (SLM) strategy to address the problem (Stringer et al., 2007). SLM refers to practices through which land users can meet their needs and derive socio-economic benefits from the land, while simultaneously ensuring long-term productive potential and maintenance of the land's environmental functions (WOCAT, 2010). In addition to NAPs, countries develop sector-specific policies that treat land degradation as a cross-cutting issue. This cross-cutting nature demands the integrated assessment of different kinds of land uses and management, and information that can help policy makers to prioritise actions to enhance ES delivery (and/or avoid ES losses), and promote SLM within decision making (Akhtar-Schuster et al., 2011). In turn, this requires integrated, holistic methodologies that bring together socio-economic, environmental and policy dimensions (Bateman et al., 2013; Costanza et al., 2014).

Various analytical frameworks can quantify and value ES, providing useful information for the public and policymakers (e.g. TEEB, 2010). For example, the monetary value of ES can be conceptualised as the way in which they contribute to different elements of the 'Total Economic Value'. ES may increase an individual's welfare through direct provision of goods (e.g., food or recreational use), or indirectly through e.g. the regulation of water and carbon cycles (TEEB, 2010). People also value ES for their non-use (also termed "passive-use") benefits. However, these conventional monetary

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valuation approaches do not capture shared values, which people hold for others and the communities and society in which they live (Kenter et al., 2014). This presents the need to integrate these various dimensions through mixed-method approaches that combine deliberative-based techniques, where varied stakeholders' perspectives are brought together. Fish et al. (2011) identify Multi-Criteria Decision Analysis (MCDA) as an effective decision making tool to evaluate the non-monetary and monetary costs and benefits of different management options. MCDA offers a useful integrative approach that also allows cultural and shared values related to ES to be assessed in a systematic way based on key socio-economic, policy and environmental priorities (Kenter et al., 2014).

Following the de Groot et al. (2010) ES classification, in this paper we present an analytical framework using MCDA to identify the multiple monetary and non-monetary dimensions of land use and management in southern Kgalagadi District, Botswana. We identify, value and score ES benefits from four types of land management: (i) private (fenced) cattle ranching, (ii) (unfenced) communal livestock grazing, (iii) (private) game farming and (iv) Wildlife Management Areas (WMAs). We then discuss the costs and trade-offs associated with ES delivery under each of these options. Our approach provides decision makers with a valuable analytical example that can be used to better understand ES provision across semi-arid rangelands, while findings can be used to inform measures that could reduce degradation of particular ES and advance SLM.

## 2. Materials and methods

### 2.1. Study area

Data were collected during 2013–2014 along an east–west transect of the southern part of Kgalagadi District, Botswana (Fig. 1), incorporating a total area of *c.* 66,000 km$^2$ (Government of Botswana (GoB), 2003) and an estimated human population of 30,000 (GoB, 2012a). Rangeland degradation has led to extensive bush encroachment (Thomas and Twyman, 2004); reducing good quality grazing and increasing rural poverty levels (Chanda et al., 2003). Land uses include communal grazing areas (unfenced cattle posts) (*c.* 14,800 km$^2$), privately owned (fenced) cattle ranches (*c.* 8,900 km$^2$), private game ranches (*c.* 800 km$^2$) and Wildlife Management Areas (WMAs) (*c.* 14,800 km$^2$) designated as protected conservation areas around the National Parks (Kgalagadi Transfrontier Park, *c.* 26,700 km$^2$).

### 2.2. Methods

We use MCDA as a framework that allows monetary-based techniques to be integrated with non-monetary ecological and shared values (de Groot et al., 2010; Kenter et al., 2014). This allows us to rank alternative options by quantifying, scoring and weighting a range of quantitative and qualitative criteria (Fontana et al., 2013). Scoring was undertaken by the project team (composed of national and international researchers with expertise in land policy, livelihoods, ES valuation, land degradation assessment, range ecology, geomorphology and environmental economics). Weighting was undertaken in consultation with stakeholders from the government and NGOs.

#### 2.2.1. Problem definition

The research problem was defined as: "Which land uses and land management strategies are best placed to generate the widest range of economic and non-economic values linked to specific ES delivered in Kalahari rangelands in southern Kgalagadi District, Botswana?".

#### 2.2.2. Identification of options, criteria definition and assessment

Four land uses which include all the key land uses in the study area were defined as MCDA options: (i) communal livestock grazing; (ii) private cattle ranches; (iii) private game ranches; (iv) WMAs. Performance of the options was measured by their
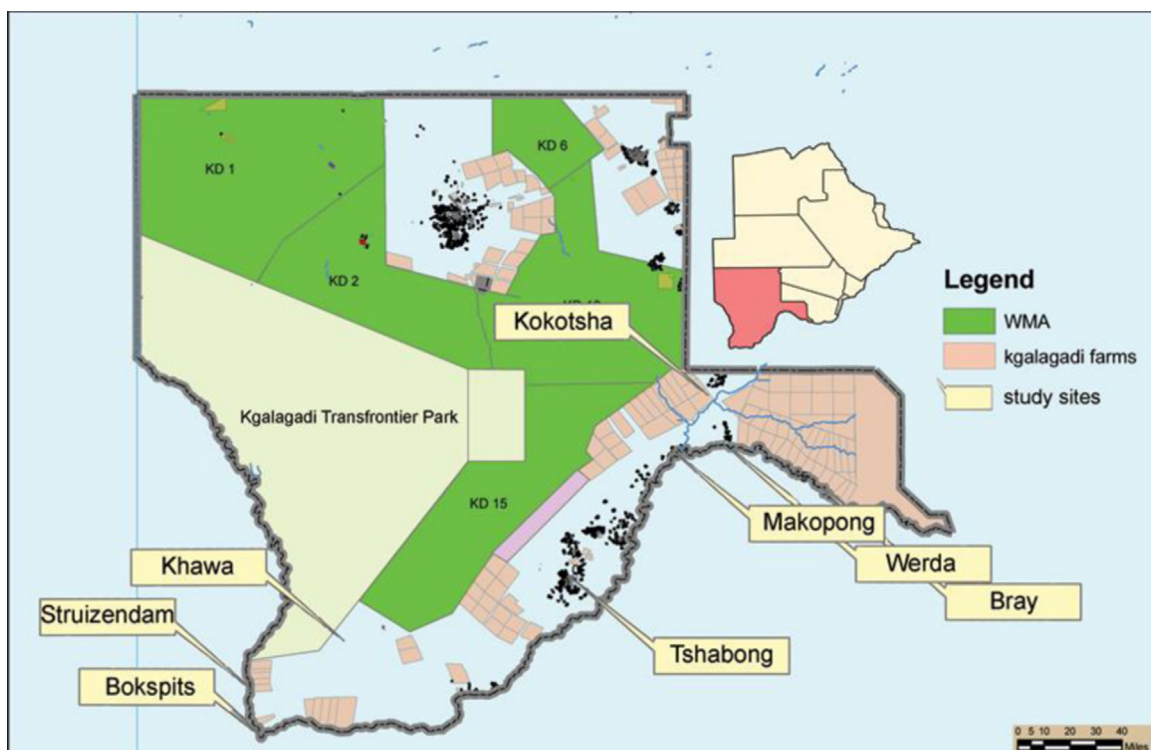


**Fig. 1.** Land use of Kgalagadi District, southern Botswana and study sites *Source*: adapted from KGLB (2013).