Integrating ecosystem services into conservation assessments: A review

2.1 Abstract

The last two decades have seen general increase in the number of conservation assessments as well as research on ecosystem services. The concept of ecosystem services have garnered considerable academic attention with the publication of more than 2400 papers focusing on the ways to map, value and estimate these services (Brown *et al.,* 2013) and how ecosystem services relate to biodiversity. Although biodiversity underpins most ecosystem services, there is a call to include ecosystem services into conservation assessments. The main reason to integrate them is to shift from strictly biodiversity conservation plans towards plans that include human well-being. At the moment there is no widely accepted approach in prioritising areas important for ecosystem services. The aim of this study was to review the extent to which ecosystem services have been included in the conservation assessments and which ecosystem services are frequently included or mentioned in conservation assessments. I identified 425 publications which focus on conservation assessments, and randomly selected 100 publications for review. Only 24% of the conservation assessments have included ecosystem services as the reason for conservation while 37% referred to ecosystem services as one of the features used to identify priority areas, 26% used ecological process which can be translated into ecosystem functions and the remaining 13% of the conservation assessments did not include ecosystem services at all. From the review, it was clear that there is an increase in number of conservation assessments which have included ecosystem services, and this is likely to continue. The frequently-used ecosystem services in conservation assessment are provisioning and regulating services, while cultural services did not feature in many assessments. I concluded by looking at the constraints and opportunity for integrating ecosystem services into conservation assessments.

Keywords: *Biodiversity assessment, Ecosystem services, Conservation planning, integrated approach.*

2.2 Introduction

The past 30 years have witnessed an impressive development of the theoretical framework and analytical tools used for land use planning particularly in the identification of areas and actions aimed at biodiversity conservation (Nim *et al.,* 2016). Systematic Conservation Planning (SCP) is a structured approach that provides the context needed to meet two basic objectives: representativeness, the need to protect the full variety of biodiversity at all its levels of organisation; and persistence, the long term survival of species and ecosystems (Margules & Pressey 2000, Bright *et al* 2008, Drielsma *et al* 2014, Larson *et al* 2016). In contrast to many conservation assessments, SCP not only identifies priority areas for conservation action but more importantly, it develops an implementing strategy. In literature these terms have been used interchangeably as if they are similar.

Conservation planning has traditionally focused on identifying key areas for the conservation of biodiversity (Luck *et al.,* 2012). Only recently have ecosystem services been included in conservation assessment. For example Egoh *et al.,* (2011) identified priority areas for ecosystem services in the grassland biome in South Africa. In the face of increasing land-use changes, a methodological approach that integrates ecosystem services and biodiversity is important (Nim *et al.,* 2016). The inclusion of ecosystem services into conservation planning would allow for the development of an integrated approach to evaluate the merits and congruency of different conservation objectives (Egoh *et al.,* 2007) but the links between biodiversity and ecosystem services are complex and there are no simple answers in integrating them (Costanza *et al.,* 2007).

The spatial overlap between habitats important for providing different ecosystem services and biodiversity benefits is of critical importance for land management strategies (Anderson *et al.,* 2009). These spatial overlaps will provide win-win situation for both biodiversity and ecosystem services or it can highlights the areas where there can be trade-offs between biodiversity and ecosystem services. An integrated approach is an ideal solution with pressures from land use changes. With an increase in the recognition of the importance of ecosystem services, it is time for conservation efforts to explicitly include ecosystem services priorities along biodiversity priorities (Egoh *et al.,* 2012).

Though ecosystem services have gained much attention in the last two decades, a widely endorsed methodology for planning for ecosystem services does not exist (Balvanera *et al.,* 2001; Egoh *et al* 2007; Schneiders *et al.,* 2012; Mascarenhas *et al.,* 2015), but different approaches have been used in different studies in ecosystem services planning. In order to contribute towards the development of such a methodology, this study conducts a survey of the peer reviewed literature on conservation assessments. This is a follow up study from Egoh *et al.,* (2007), who did similar review 10 years ago; the current study seeks to assess any significant changes in the integration of ecosystem services into conservation assessments. The focus of this review will be on conservation assessments, and less on the implementation aspect because of the complexity of reviewing the inclusion of ecosystem services after plans have been implemented.

This study assessed the ways and extent to which ecosystem services have been integrated into conservation assessments by evaluating three questions: 1) to what extent have ecosystem services been included as features in conservation assessments? ; 2) What types of ecosystem services have been included? ; and 3) how have these services been accounted for in conservation assessments? The study concludes by looking into opportunities and constraints for incorporating ecosystem services into conservation assessments.

2.3 Methods

2.3.1 Scope of study

The number of studies done in ecosystem services has contributed to numerous definitions for ecosystem services. Depending on the study aims and objectives, these definitions range from looking into direct human benefits towards economic incentives provided by ecosystem services to ecological functions and processes. These definitions are often competing and do not standardise the meaning, constraints and measurement of ecosystem services (Egoh *et al.,* 2007). The terms ecosystem value, ecosystem function, ecological services, ecosystem economics and payments for ecosystems are sometimes used to represent ecosystem services. We define ecosystem services as the benefits humans derive from nature at no costs (MA, 2005; Chan *et al.,* 2016) and our focus is only services from natural functioning ecosystem. For an ecosystem service to be considered as a service there should be direct or indirect human benefits associated with it.

The critical issue that needs attention in ecosystem services assessment is the knowledge on how ecosystem services are produced and maintained, how they are affected by system changes such as land use change, and how they depend on different levels of biodiversity (Balvanera *et al.,* 2015). The study was limited to the terrestrial environment as there are not many studies that have been carried out in the marine environment (Liquete *et al.,* 2013). Although recently there have been a number of marine studies which have looked into integrating ecosystem services in marine spatial plans. Further this allowed for the comparison of the study done by Egoh *et al.,* (2007) which focused only on terrestrial environment. Though this enabled comparison, it potentially missed an important aspect in understanding the extent to which ecosystem services are integrated in marine assessments.

2.3.2 The Review

According to Egoh *et al.,* (2007), ecosystem services were not explicitly included in conservation assessments despite the calls from research to be included in conservation assessments. Since their findings, there has been an increase in both ecosystem services mapping and modelling, and biodiversity assessments (Egoh *et al.,* 2012) but it is not clear if the inclusion of ecosystem services into conservation assessments has resulted in an increase in their inclusion in conservation assessments. This review seeks to assess the status quo on the inclusion of ecosystem in biodiversity assessments. I first made use of the Web

(www.sciencedirect.com) to search and download peer-reviewed publications from 2007 to 2015. I choose 2007 as a starting point since this is the follow up study from Egoh *et al.,* 2007.

I used these phrases to search: "ecosystem services", "ecosystem service evaluation", "priority area identification", "bioregional planning", "ecoregion assessment", "conservation planning", "conservation assessment" and "conservation planning. The first search with multiple search terms produced a great number of studies on conservation planning. I therefore narrowed my search to fewer search terms as follows: "conservation assessment", "conservation planning", and "conservation plan" to search for the publications. I felt that these phrases match with our aims and objectives of this review.

I identified 425 publications from our search which have been published between 2007 and 2015, I excluded 2016 publications for the review analysis but they were used only as supporting material in literature review. I used random stratified selection to selected 100 publications and I tried to select at least 10 publications per year to ensure good representation of all the reporting years and to avoid bias towards certain years. The remaining 325 publications were not used in the review analysis besides as supporting material for the study. I analysed these 100 publications to answer question which looks at the extent of how ecosystem services are included in conservation assessment.

To answer the remaining two questions: 2) what types of ecosystem services have been included? and 3) how have these services been accounted for in conservation assessments? We did another search from the 100 selected publications, by using the phrase "ecosystem services"; and we got 21 publications which have included ecosystem services. These publications from our second search were used to address the last two questions; and they mainly focus on ecosystem services and biodiversity conservation.

To identify which ecosystem services have been mentioned or included in conservation assessment, we divided ecosystem services using Millennium Ecosystem Assessment, 2005 categories: regulatory, supporting, provisioning and cultural. Finally, we reviewed the conservation assessments in an attempt to classify the main ways in which ecosystem services have been included into conservation assessment.

2.4 Results and discussion

2.4.1 The extent of ecosystem service inclusion

Results show that there has been an increase in the number of conservation assessments that include ecosystem services in the last decades. Most recent conservation assessments seem to include ecosystem services as part of the rationale for conserving biodiversity (Figure 2). About 26% of the studies reviewed included processes which are equally important for ecosystem service delivery. Only 13 % of the conservation assessments reviewed did not include ecosystem services, these only focused on biodiversity conservation.

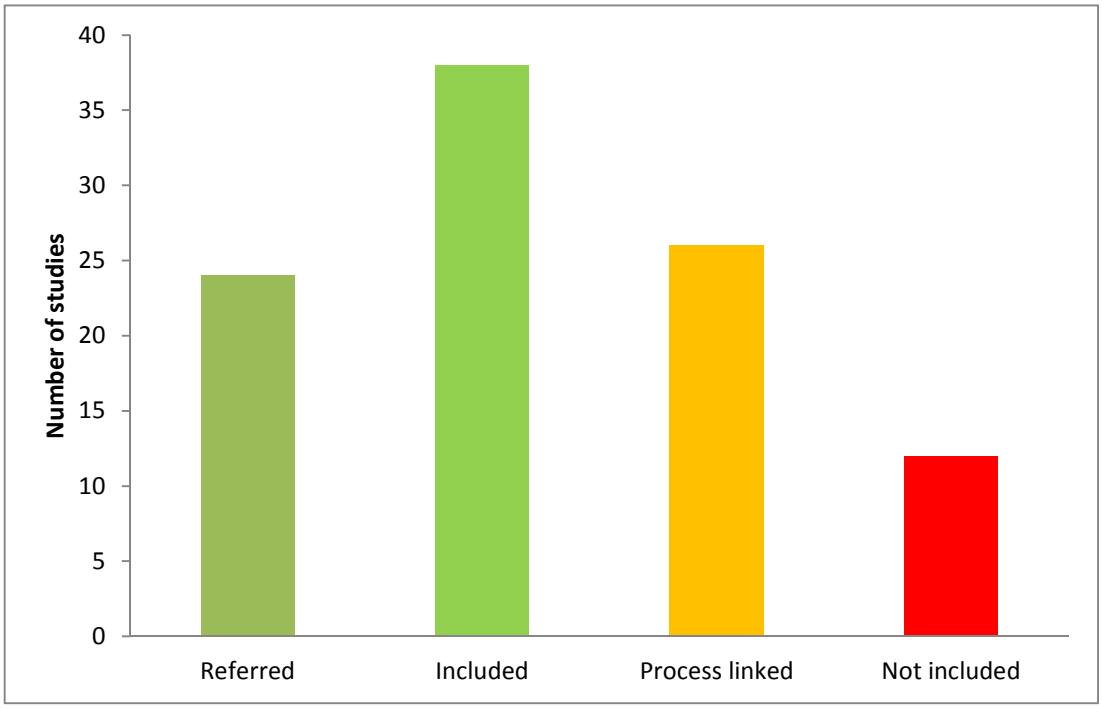

Figure 1: The extent to which conservation assessments have included ecosystem services in the last ten years.

The review also highlighted that species and land cover classes are frequently used in conservation assessments but ecological processes have gained much attention recently in most conservation assessments. A total of 75% of the 21 studies that explicitly included ecosystem services used these features (land cover and species) for conservation assessment. The remaining 25% of the reviewed conservation assessments directly included ecosystem services or into process linked services (Fig. 3).

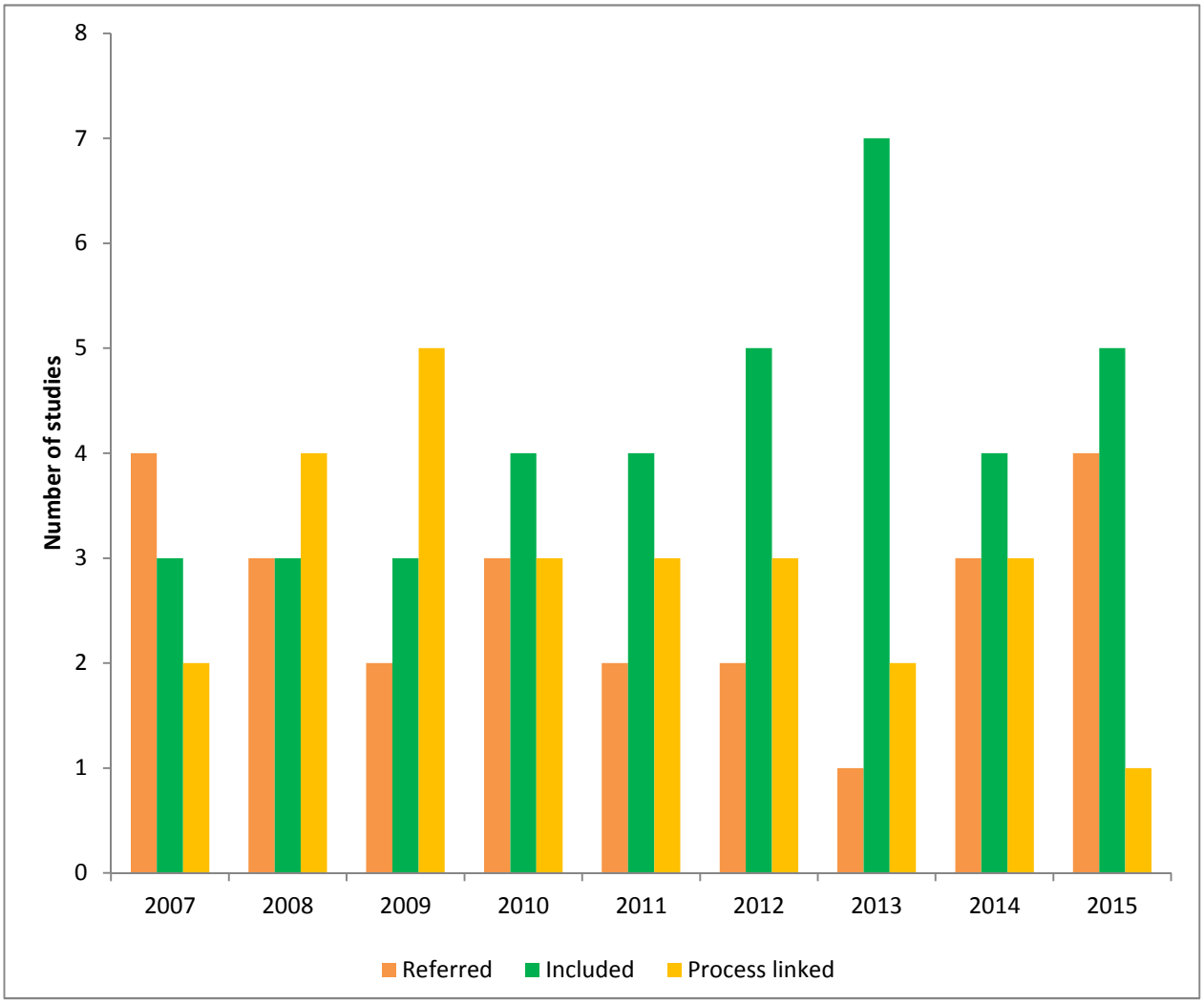

Figure 2: Integration of ecosystem services into conservation assessment over time

2.4.2 What types of services have been included?

Of the 21 publications which directly included ecosystem services in conservation assessments, the majority included regulatory (7 (33%)); provisioning services (5 (24 %)); cultural services (5 (24%)) and the least included is supporting (4 (19%)) services (Table 1). We analysed individual ecosystem services, and we found that water production and climate regulation have received most attention.

Table 1 Ecosystem services captured in 21 conservation assessments

Ecosystem service	Method of Identification	Source
Regulatory services		
Carbon sequestration	Land Cover Mapping	Geneletti 2013
Climate regulation	Climatic scenarios	Game *et al.,* 2011
Flood regulation	Mapping ES supply & demand	Morin *et al.,* 2014
Soil retention	Expert based assessment	Koschke *et al.,* 2012
Water filtration	Ecosystem assessment	Schindler & Lee 2010
Nutrient Retention	SWAT Model	Fan *et al.,* 2015
Erosion	RUSLE	Frelichova *et al.,* 2014
Supportive services		
Water resources	Ecosystem Assessment	Chunget *et al.,* 2015
Forest resources	Payment for ecosystem services	Sierra and Ruddman 2006
Forest types	Forest Resource Planning	Kilgore *et al.,* 2006
Productive areas Wildlife conflicts	MARXAN Systematic planning for conservation	Klein *et al.,* 2009 Hermoso *et al.,* 2015
Provisioning services		
Water supply	Expert mapping	Egoh *et al.,* 2010
Fuelwood	Expert based assessment	Koschke *et al.,* 2012
Timber	Land Cover Mapping	Geneletti *et a*l 2013
Socio economic Natural Medicine	Land Use evaluation in the Reserve Interviewed local community	Lu *et al.,* 2007 Kari and Korhenen-Kurki 2013
Crop productivity	Agricultural research technology	Dollar & Rhodes 2007
Cultural services		
Eco-tourism	Expert Mapping	O'Farrell *et al.,* 2010
Recreational services	Expert Mapping	Anderson *et al.,* 2009
Recreational	Interviews	Brenner *et al.,* 2013
Research and education	Assessment matrix	Christie & Rayment 2012
Aesthetic value	Mapping supply and demand	Cimon Morin *et al.,* 2014

2.4.3 How ecosystem services were accounted for in conservation assessments?

Ecosystem services have been integrated into conservation assessments in different ways, depending on the nature of the study. Three main approaches have been identified: 1) biodiversity pattern; 2) ecological processes; and 3) the mapping of services. Of the 21

studies assessed, 11 (52%) used biodiversity pattern (species and land cover); 7 (33%) through the mapping of ecosystem services; and only 3 (15%) through ecological processes.

2.4.3.1 Biodiversity pattern

Biodiversity and ecosystem services are intrinsically linked: the former supports most of the services (Onaindia *et al.,* 2013) and elements of biodiversity patterns (species and habitats) are important to humans by providing vital services such as the provision of medicines, fuel wood or building materials (Egoh *et al.,* 2007). In recent studies, ecosystem services have been included in biodiversity assessments as one of the justifications for biodiversity conservation since it provides economic incentives. Bai *et al.,* (2011) argues that the maintenance of ecosystem services is often used to justify biodiversity conservation actions, because of importance of such services to human well-being.

Biodiversity pattern and ecosystem services are interrelated, and they are all affected by ecosystem changes. Factors which affect biodiversity can also affect ecosystem service delivery, and vice versa but most ecologists argue that managing one component does not translate into managing the other, hence integrated management approach is important. The significance of declines in biodiversity and consequences for ecosystem services are increasingly recognised (Balvanera *et al.,* 2015), for instance the over-exploitation of fish stocks has led to decline in marine biodiversity via by catch and fisheries collapse (Worm *et al.,* 2006).

The spatial overlap between habitats important for providing different ecosystem services and biodiversity hotspots is of critical importance when designing conservation and land management strategies (Anderson *et al.,* 2009). Currently there are no standardised tools which can be used to safeguard biodiversity and ecosystem services at once. Conserving such areas provides a win-win situation for both biodiversity and ecosystem services. Further, it is of critical importance considering the rate of land cover change. However, successful management of ecosystem services and biodiversity demands a multidisciplinary approach (Egoh *et al.,* 2009), though at present planning for both biodiversity and ecosystem is done separately.

2.4.3.2 Ecological processes

Ecological processes support the persistence of biodiversity pattern and they can form links to ecosystem services (Egoh *et al.,* 2007). Although they cannot be directly linked to human benefits, they are important for ecosystem service delivery. For example nutrient recycling is an ecological process, this cannot be translated to human benefits but its functions do provide services to human well-beings. Ecological processes focus on the structure of ecosystems (conditions of an ecosystem to deliver services) and ecosystem function.

The review found that 15% of the conservation assessments have included ecological processes which have direct links to ecosystem services. These processes underpin delivery of ecosystem services and our understanding of their role in ecosystem service delivery is increasing (Harrison *et al.,* 2014). Looking at the conservation assessments, ecological processes which are linked to climate change and water production processes have gained much attention in recent years. For example in South Africa, there have been a number of studies which have looked into ecosystem based adaptation for climate change.

2.4.3.3 Mapping of ecosystem services

Explicit mapping of ecosystem services is recognised as a key step for the implementation of ecosystem service framework in decision making (Hauck *et al.,* 2013, Nahuelhual *et al.,* 2015). However mapping is not often carried out for the actual ecosystem service but the ecosystem service provider. For example water retention function not water supply as a service can be modelled as a function of vegetation, slope and soil. Mapping of ecosystem services can combine both biodiversity pattern and ecological processes for conservation assessments. There have been different approaches in mapping ecosystem services, and the method of mapping depends on the nature of the study or ecosystem services in question. In recent years, many new mapping approaches of ecosystem services have been developed (e.g. Tallis and Polansky 2009, Nelson *et al.,* 2009, Schneiders *et al.,* 2012, Frelichova *et al.,* 2014). The mapping of ecosystem services has been listed as one key element that is required to mainstream ecosystem services into decision making (Burkhard *et al.,* 2009).

The mapping of ecosystem services sometimes uses proxies or indicators to generate spatial information about ecosystem services, for example using land cover classes to represent different services. Much attention has focused so far on the regulating and provisioning ecosystem services (Karabulut *et al.,* 2016). From our review, the most frequently mapped services were climate regulation and services related to water provisioning or regulation.

Fewer studies have mapped cultural and supporting services; Pert *et al.,* (2015) argues that the mapping and assessment of cultural ecosystem services have been limited by number of conceptual barriers, this include definitions of cultural ecosystem services which are diverse and lack consistency particularly in the economic literature, and are difficult to quantify

2.5 Discussion

Over the last decade, there has been an increase in the inclusion of ecosystem services into conservation assessments compared to the study by Egoh *et al.,* (2007). Our review found that most of the recent conservation assessments have included ecosystem services either directly or through ecological processes which are important for ecosystem service delivery. However to fully integrate ecosystem service with conservation assessments, it is helpful to develop frameworks for mapping ecosystem services which are compatible with the prevailing tools of conservation such as Marxan, Zonation, C-Plan, etc. (Chan *et al.,* 2016). Although there is inclusion of ecosystem services within conservation assessments, there still remains constrains and also opportunities which needs to be explored. Below I discuss some of these constraints and opportunities for the inclusion of ecosystem services into conservation assessments.

2.5.1 Constraints

2.5.1.1 Methodology to map ecosystem services

Most ecosystem service mapping approaches have used secondary data at broad spatial scale, and focused mainly on provisioning and regulating ecosystem services based upon biophysical assessment (Darvill and Lindo, 2014) while there has been minimal formal research and mapping of cultural ecosystem services (Crossman *et al.,* 2013). Mapping ecosystem services should go beyond the identification of ecosystem service providers and should also identify the beneficiaries of that service. Hence there are few studies which have looked into mapping both the spatial location of services and the beneficiaries of those services by mapping demand and supply (Burkhard *et al.,*2011).

It is important to standardize approaches to map ecosystem services, and clearly define what constitute an ecosystem service. At the moment there are contrasting definitions whether ecosystem services should only be limited to natural ecosystems or it should also include transformed ecosystems. Some of the studies have included both natural and transformed systems as source to ecosystem service but most studies within natural sciences concur that only natural systems should be regarded as source of ecosystem services (Baral *et al.,* 2013; Clericci *et al.,*2014). It is therefore essential that we clarify these and other uncertainties around ecosystem services before we embark on efforts to map and integrate them into conservation assessments (Egoh *et al.,* 2007).

2.5.1.2 Relationship between ecosystem services and biodiversity

Despite extensive literature on the relationship between biodiversity and ecosystem services, few studies have attempted to document ways in which aspects of biodiversity relate to ecosystem services (Egoh *et al.,* 2009, Pert *et al.,* 2010, Bai *et al.,* 2011). So is the extent to which conserving important areas for ecosystem service delivery will translate into biodiversity conservation. This translates to challenges in integrating these two concepts. While there is good understanding of biodiversity, much work needs to be done in understanding ecosystem services

While in a broad sense biodiversity underpins most ecosystem services, it is very difficult to make a direct connection between biodiversity and other ecosystem services as their relationship varies depending on the types of ecosystem services (provision, regulation, supporting) (Ng *et al.,* 2013) although they both depends on the condition of ecosystems. It is still unclear whether conserving biodiversity maintains ecosystem services and whether priority areas for ecosystem services delivery also support biodiversity conservation. Given the complex relationship between biodiversity and ecosystem services, a generic answer might never be found.

2.5.2 Opportunities

2.5.2.1 Integrated approach

Though ecosystem services and biodiversity have complex relationships and sometimes it is difficult to quantify, opportunities exist to integrate these two concepts in one assessment. Chan *et al.,* (2016) argues that integrating ecosystem services into conservation planning is helpful in developing frameworks for marginal valuation compatible with the prevailing tools of reserve design such as Marxan. These planning tools or software which are underpinned by explicit targets for biodiversity features and which generates maps of irreplaceability can lend themselves easily to assessment for ecosystem services (Egoh *et al.,* 2007). The integrated approach will provide incentives for conservation and it will also show areas where there will be trade-offs between biodiversity and ecosystem services. Understanding trade-offs, synergies and interactions will help resource managers to make better decisions and create landscapes that balance conservation with services (Baral *et al.,*2013)

2.5.2.1 Implementation of conservation assessments

The role of conservation planning is to develop conservation assessment which highlights priority areas for biodiversity conservation, but sometimes these plans are not implemented fully and not used at all. The inclusion of ecosystem services in these plans might contribute to the implementation of plans in different ways:

a) Ecosystem services has human benefits associated with them, it is likely to get recognition from policy makers which in most cases are concern with the social impacts

b) The implementation of integrated plans will have economic incentives which only biodiversity conservation plans do not provide

c) Ecosystem services within the conservation assessments may achieve many biodiversity targets under an easy-to-sell umbrella of ecosystem services.

2.7 Conclusion

The review has shown that there is progress towards inclusion of ecosystem services into conservation assessments although there are still some challenges to fully integrate the two. The challenge of modelling ecosystem services is immense, but so is the opportunity: conservation projects designed and implemented effectively can benefit people and nature; and rigorous analysis of ecosystem service benefits could be instrumental in inspiring the institutional changes needed to internalise these important values in decision making.

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