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Assessment of ecosystem services and benefits in village landscapes – A case study from Burkina Faso

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ABSTRACT

Most methods to assess ecosystem services have been developed on large scales and depend on secondary data. Such data is scarce in rural areas with widespread poverty. Nevertheless, the population in these areas strongly depends on local ecosystem services for their livelihoods. These regions are in focus for substantial landscape investments that aim to alleviate poverty, but current methods fail to capture the vast range of ecosystem services supporting livelihoods, and can therefore not properly assess potential trade-offs and synergies among services that might arise from the interventions. We present a new method for classifying village landscapes into social-ecological patches (landscape units corresponding to local landscape perceptions), and for assessing provisioning ecosystem services and benefits to livelihoods from these patches. We apply the method, which include a range of participatory activities and satellite image analysis, in six villages across two regions in Burkina Faso. The results show significant and diverse contributions to livelihoods from six out of seven social-ecological patches. The results also show how provisioning ecosystem services, primarily used for subsistence, become more important sources of income during years when crops fail. The method is useful in many data poor regions, and the patch-approach allows for extrapolation across larger spatial scales with similar social-ecological systems.

1. Introduction

The majority of the world's poor depend on their surrounding landscapes for multiple ecosystem services that underpin their livelihoods (WRI et al., 2005). Seventy percent of the 1.4 billion people living on less than US$ 1.25 a day live in rural areas where agriculture is a major livelihood activity (IFAD and UNEP, 2013), and where the majority only has access to small (< 2 ha) areas of agricultural land (World Bank, 2007). Substantial investments are currently being made in agriculture to reduce the large yield gaps (see e.g. Dzanku et al., 2015) that exist across smallholder systems with the intention to increase food security and reduce poverty. In order to obtain sustainable poverty alleviation and food security, it is important to ensure that these investments are done without unintentional trade-offs with other ecosystem services on which the population also depends. Spatially explicit tools that identify, map, and model ecosystem services in response to different investments are therefore becoming increasingly important for decision makers and land use planners (Burkhard et al., 2013; Crossman et al., 2013). These tools can help facilitate the design and targeting of interventions aimed at improving agriculture and alleviating rural poverty, and explicitly deal with ecosystem service trade-offs resulting from different policy and management changes.

Several reviews on spatial analyses of ecosystem services (e.g. Crossman et al., 2013; Egoh et al., 2012; Malinga et al., 2015; Martínez-Harms and Balvanera, 2012) have highlighted that these analyses have so far focused mainly on regulating services and have used secondary data (e.g. land cover maps and global or national databases) rather than field data. Using secondary data requires substantial amounts of available input data, which seldom exist in poor and marginalized areas where people depend heavily on ecosystems for their livelihoods (Ramirez-Gomez et al., 2015; Vrebos et al., 2014). Most mapping studies of ecosystem services have been done on large spatial scales (regional, provincial, and national), with only a very few studies comparable to the size of a village (Malinga et al., 2015; Martínez-Harms and Balvanera, 2012). The data used for mapping at large spatial scales often has a relatively low spatial resolution. Ecosystem services estimations vary substantially depending on the resolution of the spatial input data (Grêt-Regamey et al., 2014; Kandziora et al., 2013). Current ecosystem services assessments can thus cause misleading estimates of the provisioning ecosystem services generated and used on a very local scale, and more village level studies are needed to

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increase the spatial resolution of data.

Methodologies for studies on ecosystem services across units relevant to local stakeholders are scarce (Potschin and Haines-Young, 2013), although there are several recent studies that address this gap. These studies have used questionnaire surveys (Abram et al., 2014) and different combinations of semi-structured interviews, focus group discussions, transect walks and participatory mapping (Fagerholm et al., 2012; Paudyal et al., 2015; Ramirez-Gomez et al., 2015), sometimes combined with expert opinions (van Oort et al., 2014), to assess ecosystem services of value for local populations. These combinations of participatory methods are important contributions to ecosystem services assessments. However, there is still a gap between location specific assessments, including local knowledge, and scales at which land use planning and development interventions operate. This is partly because ecosystem services are not related to particular landscape units, which would allow for the extrapolation of results to larger areas with similar landscape configuration and socioeconomic conditions. Another aspect seldom addressed in ecosystem services assessments is the role of temporal and spatial heterogeneity for the generation of services (Verburg et al., 2009). If this heterogeneity is masked behind a single land cover or land use when mapping, the full function of the landscape cannot be assessed. This is particularly important in regions with integrated crop-livestock systems and where high rainfall variability results in highly variable landscape productivity and ecosystem services generation across space and time.

One such region is the West African Sahel. Although there is a diversification of livelihood strategies in the region (see e.g. Nielsen and Reenberg, 2010), the population here depends heavily on provisioning ecosystem services from the local landscape for their livelihoods, with 68% of revenues coming from livestock and crop production and 45% of food sources coming from subsistence activities (INSD, 2003). Current production systems have very low yields (300–1000 kg/ha; FAO, 2014) and experience a high probability of yield reductions due to the high rainfall variability (Lemoalle and de Condappa, 2010). The majority, 74–92%, of the population suffers from multidimensional poverty with deprivations that include a combination of health, education and standard of living indicators (UNDP, 2013).

Studies from a range of fields have demonstrated the many ways in which Sahelian smallholders rely on their local landscapes; however, no study has linked landscape pattern to the generation of provisioning ecosystem services in a comprehensive way. Studies within the *terroir*-school, for example, offer detailed descriptions of natural and anthropogenic features as well as management in the rural landscape (see e.g. Kohler, 1971; Marchal, 1983), but they do not provide an overview of resource use from different landscape units. In the ethnobotanical literature, ecosystem services such as nutritional and medicinal use of fruits and leaves and, to some extent, the use of firewood and construction materials, are emphasized (see e.g. Belem et al., 1996; Lykke et al., 2004; Zizka et al., 2015). However, this literature does not give a spatially explicit understanding of where in the landscape they are harvested, making it difficult to attribute these services to specific land units. Similarly, agroforestry literature on, for example, Sahelian parklands (crop fields with scattered trees) provides an understanding of the multiple contributions to livelihoods that come from parkland trees (see e.g. Gustad et al., 2004; Faye et al., 2010). However, this is limited to the consideration of only one land unit, i.e. fields with trees (with one exception in Gakou et al., 1994), which makes it difficult to understand the relative contribution to livelihoods of these parklands compared to e.g. shrublands that co-exist in the landscape.

Our study addresses the need for a more nuanced understanding of the multi-facetted dependence that people have on their local landscapes in order to guide management and interventions. One key challenge is to map landscape units relevant for local people that include local knowledge of priority ecosystem services, and then up-scaling to a scale that can be used in development interventions without loss of relevance for the local people. This issue is particularly pressing in areas such as the West African Sahel, where it is needed to guide much-needed investments in agriculture and poverty alleviation in a context where secondary data is scarce, dependence on local provisioning ecosystem services is high, and climate change is expected to make the generation of ecosystem services more unpredictable. This paper is a first step in addressing this need. Its focus and novelty is in tracking the contribution of locally relevant landscape units to multiple ecosystem services, analyzing how these ecosystem services translate into different livelihood benefits, and studying how these flows vary with inter-annual differences in rainfall. We specifically address the following questions: (i) What are the different units in village landscapes (the land belonging to a village as defined by the villagers) that are relevant to local people? (ii) Which set of ecosystem services is generated in each of these units? (iii) What benefits do these services contribute to livelihoods, and how do benefits for livelihoods change under different rainfall conditions?

2. Methods

The fieldwork was carried out in six villages, located in the Nord and Centre-Nord administrative regions of Burkina Faso (Fig. 1). These regions are interesting areas for ecosystem services research for at least two reasons. First, they have for several decades been focal areas for interventions aiming to combat land degradation and improve landscape productivity (Reij et al., 2005; Stith et al., 2016). Second, while remote sensing studies show that vegetation has increased across parts of the Sahel over the past 30 years, rainfall alone cannot explain the increase in vegetation in these two regions (Herrmann et al., 2005; Stith et al., 2016). This suggests that management practices may have played an important role in changing the landscape, possibly also impacting the generation of ecosystem services.

We chose the village landscape as our focal spatial scale, which is a relevant scale since almost all land in the regions belongs to villages, hence the landscape units found in villages are the main units that can be found across the regions. We introduced the concept of social-ecological patches to characterize the landscape and use it as a unit for ecosystem services assessment. Social-ecological patches are landscape units (subunits of the village landscape) that correspond with the words that local people use when describing their landscapes, characterized by a combination of land use, land cover and topography. The social-ecological patch concept is a way to spatially describe land systems that generate multiple ecosystem services (Verburg et al., 2009). The social-ecological patch concept is different from other landscape classifications commonly used in ecosystem services assessments as it takes into account social-ecological interactions, acknowledges seasonal change in how the unit is used, and is not defined by the conditions for generation of individual ecosystem services, which allows us to attribute sets of ecosystem services to each patch (Table 1). This provides opportunities to scale up results from villages to municipalities or provinces with similar social-ecological conditions.

We defined ecosystem services as co-produced in social-ecological landscapes (sec. Reyers et al., 2013) meaning that they are shaped by geobiophysical and social processes. We separated between ecosystem services and benefits from these services (as in for example Fig 2. in de Groot et al., 2010). For example, production of shea