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Application of systematic monitoring and mapping techniques: Assessing land restoration potential in semi-arid lands of Kenya

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1. Introduction

Drylands cover over 40% of the earth's surface and support over 2 billion people, globally (Millennium Ecosystem Assessment, 2005). In East Africa alone, over 250 million people depend on drylands for their livelihoods (De Leeuw et al., 2014) and in Kenya, 70% of the total land area is classified as arid- and semi-arid (Batjes, 2004). Over the last several decades, an increasing and more sedentary human population has resulted in more pressure on these lands, and an expansion of agricultural production into marginal dryland areas that were traditionally rangelands. The result is widespread soil loss and land degradation, as well as increased pressure on protected areas and more frequent human-wildlife conflict in Kenya (Laikipia Wildlife Forum, 2012; Nyamwamu, 2016). These factors, combined with climate change and erratic rainfall, continue to increase the vulnerability of drylands in East Africa (Darkoh, 1998). However, drylands are also considered to have an important role in mitigating climate change (Lal, 2004; Neely et al., 2009; Neely and De Leeuw, 2008), are important biodiversity hot-spots and support a diversity of livelihoods (Mortimore, 2009). While land degradation is recognized as a major cause of low agricultural and rangeland productivity, estimates of land degradation within the drylands remain poor and hence also vary widely. For example, the (Millennium Ecosystem Assessment, 2005) estimated that between 10% and 70% of global drylands are degraded. The application of remote sensing, coupled with systematic field assessments, for monitoring, assessing and mapping land degradation patterns and severity within landscapes has the potential to significantly improve current estimates of land degradation, while at the same time allowing for spatially explicit targeting of restoration options and monitoring of change over time. Such advances will also ultimately make assessments of the drivers of land degradation in drylands possible, which is critical for successful restoration and for avoiding further degradation.

Several studies highlight soil erosion as an important process of land degradation (Dregne, 2002; Mortimore, 2009; Tiffen and Mortimore, 2002; Vågen et al., 2013a), and as important indicator of land health due to its negative impacts on soil health and overall land productivity. Furthermore, poor agricultural and rangeland management practices are leading to loss of soil organic carbon (SOC), mining of soil fertility, increased soil compaction, as well as water and wind erosion. These processes, which are often confounded by climate change and the high levels of susceptibility to degradation in drylands often result in loss of overall system productivity and resilience even under moderate stress (Darkoh, 1998; Vågen et al., 2013b; Vågen and Gumbritch, 2012). Degraded lands, continually put into production, without restoration or other conservation measures, can become irreversibly unproductive, jeopardizing the livelihoods of millions of people who depend on these systems. Thus, ecosystem restoration has become an important field of research (Aronson and Alexander, 2013; Crouzeilles et al., 2016; Dobson et al., 1997; Itto, 2002; IUCN and WRI, 2014; Lapstun, 2015; Suding et al., 2015; Williams-linera et al., 2011; Young et al., 2005), especially in dryland areas (FAO, 2015; Herrick et al., 2013; Riginos and Herrick, 2010).

A growing number of international initiatives are dedicated to restoration of degraded lands, most notably the Bonn Challenge (www.bonnchallenge.org) and AFR100 (www.afr100.orgu. In addition, the concept of land degradation neutrality (LDN) was adopted as a target for Sustainable Development Goal (SDG) 15 (Cowie et al., 2018; UNCCD, 2016). Sustainable Development Goal (SDG) 15 aims to “protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss”. Indicators agreed upon included trends in land use/cover, land productivity and soil organic carbon stocks. In order to support this agenda, methods and approaches that are scientifically rigorous and applicable to a range of

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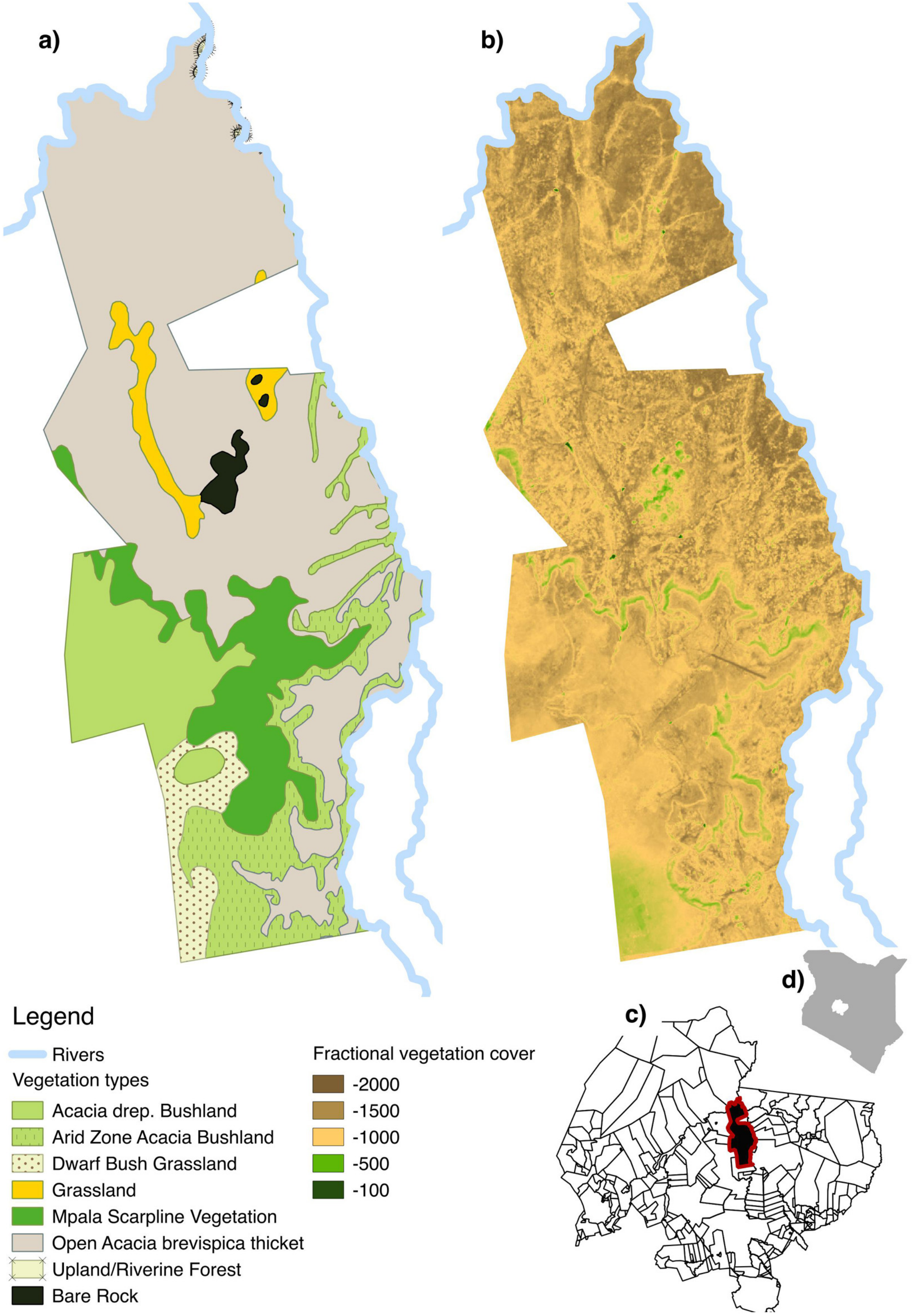

Fig. 1. Overview maps showing: a) Vegetation classes in Mpala Ranch b) Fractional vegetation cover across Mpala ranch, calculated using Soil Adjusted Total Vegetation Index (SATVI); c) Map of the administrative boundaries within Laikipia county with the location of Mpala Ranch highlighted; and d) Map of Kenya, showing the location of Laikipia county in white.

different ecosystems at multiple scales are needed to assess and monitor land degradation. To aid country practitioners in carrying out restoration activities, the International Union for the Conservation of Nature (IUCN) and the World Resources Institute (WRI) created a guide to assess opportunities for forest landscape restoration, where they highlight the need for more reliable spatial data for assessing restoration potential (IUCN and WRI, 2014). However, major gaps still exist in methods to assess land degradation, particularly for spatially explicit assessments at scales necessary for targeting interventions (Davies et al., 2012; Lal, 2004; Mortimore, 2009).

In the current paper we apply a systematic approach to the assessment of land health with a case study in a Kenyan dryland system in Laikipia County. We argue that such a systematic approach is critically important for addressing the challenges of land degradation, for