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Economic impacts of *Prosopis spp*. invasions on dryland ecosystem services in Ethiopia and Kenya: Evidence from choice experimental data

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ABSTRACT

Biological invasions can induce trajectories of changes that make ecosystems fragile and less reliable in providing services and goods. Here we set out to assess the economic value of dry land ecosystem services affected by the invasive tree Prosopis, which was originally introduced in Africa and elsewhere for providing firewood, animal fodder and other services to rural people. Based on choice experiment method, we estimated the economic values of dry land ecosystem services affected by Prosopis in the heavily invaded Afar region, Ethiopia and Baringo County, Kenya. Including labor and cash contributions as payment attributes, a random parameters logit model was employed for analyzing households' preferences for the affected ecosystem services. We found that, despite the services provided by Prosopis, households from both regions were willing to pay for its management primarily driven by biodiversity and water. WTP was on average higher in Afar (USD 50.42/year) than in Baringo (USD 37.74/year), which may be because the ecosystems in Afar were less degraded prior to the invasion by Prosopis than in Baringo and that charcoal production in Afar is officially prohibited. Our results indicate that the costs imposed by the deliberately introduced Prosopis outweigh its benefits in both Afar and Baringo.

1. Introduction

Dryland ecosystems in Eastern Africa provide numerous goods and services to about 30 million pastoralists and agro-pastoralists (Davies and Hatfield, 2007; Kassahun et al., 2008). For example, their products constitute 35% and 50% of the agricultural gross domestic product (GDP) in Ethiopia and Kenya, respectively (Davies and Hatfield, 2007). In addition, dryland ecosystems in Eastern Africa are home to a large diversity of charismatic animal and plant species supporting cultural services such as tourism (Witt and Luke, 2017). However, over the past decades the dryland ecosystems of the region have experienced broad and dynamic trajectories of ecological degradation, with significant socio-economic consequences for the rural communities inhabiting these ecosystems (Martín-Llópez et al., 2008). Key factors driving degradation of dryland ecosystems degradation in Eastern Africa include over-grazing, conversion to agriculture and enchroachment by invasive alien species (IAS) (Witt and Luke, 2017).

Prosopis spp. (hereafter referred to as *Prosopis*) is a group of closely related woody plant species and hybrids that were introduced in the region in the late 1970s and early 1980s for different environmental and socio-economic benefits (Pasiecznik et al., 2001). For instance, *Prosopis* was introduced in Ethiopia to curb desertification (Haregeweyn et al., 2013) and in Kenya to alleviate the negative effects of deforestation (Mwangi and Swallow, 2008). *Prosopis* can also serve as shade and wind break, as a source for firewood, charcoal production and construction material and regulate microclimate (Pasiecznik et al., 2001; Maundu et al., 2009; Tilahun et al., 2016).

However, soon after its introduction, *Prosopis* started escaping from the plantations and invading the surrounding natural and semi-natural ecosystems, thereby threating biodiversity, reducing fodder for livestock production and causing ground water depletion (Maundu et al., 2009; Wise et al., 2012; Shackleton et al., 2014). In addition, its rapid encroachment into pathways, homesteads and water points limits mobility of animals and humans and causes body injury (Mwangi and Swallow, 2008; Haregeweyn et al., 2013; Ayanu et al., 2015).

In Eastern Africa, some uncoordinated attempts have been made to manage the invasion of *Prosopis*, but with little success so far. Invasion appears to continue at an alarming rate, thereby creating fragile and less resilient ecosystems (Maundu et al., 2009; Ilukor et al., 2016; Wakie et al., 2016). A possible explanation of the lack of a concerted action to manage *Prosopis* in the region may be a lack of sound quantitative and comprehensive empirical monetary values on the impacts

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of the invasion (Martín-Llópez et al., 2008; Wise et al., 2012; Costanza et al., 2014). Understanding the changes in ecological and socio-economic values due to ecosystem degradation is essential for making empirically sound decisions in environmental management (Martín-Llópez et al., 2008; Gómez-Baggethun et al., 2009; Pejchar and Mooney, 2009; Costanza et al., 2014; Freeman et al., 2014). Yet, the intricate nature of the dryland ecosystems in Eastern Africa and the societal values that govern pastoralists' and agro-pastoralists' economic and social interactions with their environment pose critical challenges in estimating values on the economic consequences of the pressure *Prosopis* exerts on pastoral and agro-pastoral ecosystems. In these dryland ecosystems, most natural resources are common property (rival but non-excludable) and have non-market values in which conventional market systems and privatization frameworks are inapplicable for valuating impacts on environmental resources (Sagoff, 1998). To assess the value of ecosystem services (ES) affected by IAS, or by their management, an approach that is suitable for non-market services should be applied to estimate values of ecosystem goods and services, rather than using conventional methods used for producing valid market-value estimates (Costanza et al., 2014).

A plausible way to overcome such challenges is to consider the changed value perceived by the community that generates benefits from a given ecosystem (Pearce and Turner, 1990; Sagoff, 1998; Kontoleon et al., 2007; Barkmann et al., 2008; Gómez-Baggethun et al., 2009; Kenter et al., 2011; Costanza et al., 2014; Vaz et al., 2017). Values which a community attaches to communal resources are functional in the framework of theory of collective action wherein individual members in the collectivity coordinate efforts to solve their communal encounters (Kenter et al., 2011; Freeman et al., 2014). Hence, economic valuation via willingness-to-pay (WTP) estimation of the effects of IAS on ES using ecosystem service approach (MA, 2005; Barkmann et al., 2008) can be a viable solution since it enables to comprehensively valuate the intricate linkage between the ecosystem and human welfare (Pejchar and Mooney, 2009).

The main aim of this study was to estimate the monetary values of ES affected by *Prosopis* in the drylands of Afar National Regional State (hereafter called Afar) in Ethiopia and Baringo County (hereafter called Baringo) in Kenya. The study was guided by the following questions: What ES are given due attention by the local communities in managing *Prosopis* invasion? Is there preference heterogeneity among households (HHs) in the study areas? What are the socio-economic determinants of preference heterogeneity that affects communities' WTP for *Prosopis* management strategies that can bring improvements in ES? What is the estimated economic value of the affected ES? In addition to these primary aims, the study intended to show the applicability of choice experiment (CE) method in ES valuation in subsistence economy of developing countries.

The underlying hypothesis was that the local communities in the study areas perceive that the negative effects of *Prosopis* invasion outweigh its positive effects and that they are willing to contribute to *Prosopis* management that will reduce the negative effects of *Prosopis* on ES. However, due to differences in perception (Barkmann et al., 2008; García-Llorente et al., 2008), HH demographic and socio-economic characteristics (Adamowicz et al., 1998; Train, 2003; Colombo et al., 2009; Kenter et al., 2011; Tilahun et al., 2016) preference heterogeneities are likely to prevail among HHs in the study areas. Further, owing to institutional differences, WTP may differ between HHs from Afar and Baringo.

2. Methods

2.1. Study areas

Both Afar Region in Ethiopia and Baringo County in Kenya are part of the Great Rift Valley of Eastern Africa. Afar Region is located between 39°34′ and 42°28′ East Longitude and 8°49′and 14°30′ North Latitude in the northeastern part of Ethiopia covering about 270,000 km^2. The region covers about 10% of the total landmass of Ethiopia and about 29% of pastoral lowlands. The region is in arid and semi-arid part of the country, with a mean annual temperature of 31 °C. Rainfall is erratic and scarce with annual precipitation between 200 mm and 600 mm. The major watershed in the Afar region is the Awash River Basin. The population of the region is estimated to be about 1.77 million (CSA, 2015). Pastoralism is the most dominant production system (87%). Agro-pastoralism which has emerged following development of small-scale irrigation schemes, accounts only for 13% of the economy. The Afar people highly depend on Awash River flood plain for grazing their livestock during the drought periods and for small-scale irrigation. Currently, the flood plains are either highly invaded or under risk of invasion by *Prosopis* (Ayanu et al., 2015; Ilukor et al., 2016).

Baringo County covers an area of 1015 km^2 and lies between Latitudes 0°13″ South and 1°40″ North and Longitudes 35°36″ and 36°30″ East (Mwangi and Swallow, 2008). The County has two distinct weather patterns, with temperatures in the southern part ranging between 25 °C during the cold months (June and July) and 30 °C during the hot months (January and February) while in the northern parts, temperatures range between 30 °C and 35 °C. It receives between 1000 mm and 1500 mm of rainfall annually in the highlands and 600 mm in the lowlands. The county has two rainy seasons, March to June (long rains) and November (short rains). The major economic activities include pastoralism, agriculture, honey production and sand harvesting (Maundu et al., 2009). Agricultural activities include dairy farming and maize, groundnuts, cotton and coffee production dominantly in the highlands. Pastoralism is practiced in the low-lying plains of the county where rearing of goats, sheep and cattle are the dominant livestock activities.

The main vegetation types in the two study areas comprise bush land, shrub land, riverine forests, grasslands and seasonal marshes and swamps. Currently, however, these vegetations are facing *Prosopis* encroachment.

2.2. Sampling procedure and survey administration

A combination of probability and non-probability sampling designs were applied at different stages of sample selections in each study area. Afar Region and Baringo County were selected purposively as both areas belong to the most heavily invaded areas in East Africa. In Afar, Amibara, Gewane and Awash Fentale districts were randomly selected from highly, moderately and low invaded districts, respectively. Following this, Kebeles with mean *Prosopis* invasion levels of 4–59% were identified in all the three districts in consultation with community representatives and local experts. Subsequently, using proportionate random sampling technique, five, three and two Kebeles were selected from Amibara, Awash Fentale and Gewane districts, respectively. The last stage involved simple random sampling with probability proportional to population size in selecting a total of 253 sample HHs from Afar region of Ethiopia.

Baringo County has six sub-counties of which Marigat and Kabarnet sub-counties are *Prosopis* invaded. From the two invaded sub-counties, Marigat sub-county was purposively selected as it is more invaded than Kabarnet. The sub-county consists of 11 locations which are further divided into 18 sub-locations. Using *Prosopis* invasion levels, these sub-locations were stratified into three. In the same fashion used for selecting sample *Kebeles* in Afar, 10 sub-locations were selected with invasion levels ranging from 7 to 68%, and finally a total of 250 sample HHs were selected using simple random sampling with probability proportional to population size. In both study areas, we used household as the unit of analysis.

Surveys were administered by trained local enumerators. In recruiting enumerators three main criteria were used in both the study areas; a minimum of diploma degree, experience in administering