



Analysis

Human Appropriation of Net Primary Productivity and Rural Livelihoods: Findings From Six Villages in Zimbabwe



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ABSTRACT

The African land system is undergoing rapid change, and novel approaches are needed to understand the drivers and consequences of land use intensification. Human Appropriation of Net Primary Productivity (HANPP) is a powerful indicator of land use intensity, but has rarely been calculated at high spatial resolutions. Based on data from six villages in Zimbabwe, we present a novel method of calculating HANPP at community and household scales, and explore to what extent household wealth is related to NPP appropriation. HANPP at the village scale was higher than expected from previous studies, ranging from 48% to 113% of potential NPP. Loss of NPP through land use change accounted for the greater proportion of HANPP in four of the six villages, but NPP embodied in livestock feed, firewood and construction materials also contributed significantly to total appropriation. Increasing household wealth was associated with increasing appropriation of NPP in harvested resources, but not with loss of potential NPP through land use change. Our results indicate that land use intensity is currently underestimated in smallholder farming areas of southern Africa. High-resolution HANPP calculations based on field data offer an effective new approach to improving understanding of land use intensification in complex socioecological systems.

1. Introduction

Human activity is having unprecedented influence within the global land system. Over 80% of ice-free land has been altered by human impact (Sanderson et al., 2002), changing atmospheric composition, climate dynamics, nutrient cycling, biodiversity and ecosystem services (Chapin et al., 2000; Millennium Ecosystem Assessment, 2005; Foley et al., 2005). This ‘human domination of the earth’s ecosystems’ (Vitousek et al., 1997) has led to reconceptualisation of humans as integral components and engineers of the global biosphere (Ellis and Ramankutty, 2008) and the recognition of a need for novel integrated approaches, breaking down the historic barriers between natural and social science, to better understand the drivers and consequences of land use change (Kates et al., 2001; Turner et al., 2007; Hackman et al., 2014).

Human Appropriation of Net Primary Productivity (HANPP), the proportion of annual plant biomass production co-opted by human activity, was first suggested as a measure of land use intensity by Vitousek et al. (1986). Land use intensity is a complex and multi-dimensional concept (Erb et al., 2013), and the advantage of HANPP compared to simpler metrics such as fertiliser inputs (Potter et al.,

2010) or crop output (Monfreda et al., 2008) is that it is intrinsically socioecological, encompassing the interactions between human livelihoods and an ecological energy flux. Early studies quantified the annual extraction of NPP embodied in resources such as crops, livestock feed and timber as between 20 and 40% of annual global NPP (Vitousek et al., 1986; Rojstaczer et al., 2001; Imhoff et al., 2004), before Haberl et al. (2007) developed the HANPP concept further by expressing HANPP as a proportion of the potential NPP in a system undisturbed by human influence, thereby including resource extraction but also losses or gains in NPP caused by human land use change (such as deforestation or intensive agriculture). Using the latter approach, HANPP was calculated as 23.8% of potential global terrestrial NPP in the year 2000 (Haberl et al., 2007).

Land use intensification is a subject of particular research interest in sub-Saharan Africa for several reasons. Firstly, HANPP has increased more steeply in Africa over the last century than on any other continent (Krausmann et al., 2013), but yields of staple crops remain far below potential levels (Licker et al., 2010; Sanchez, 2010). Secondly, Africa has been identified as a hotspot of potential new agricultural land (Ramankutty et al., 2002; Deininger et al., 2011; Lambin and Meyfroidt, 2011; although see Young, 1999; Chamberlin et al., 2014), but

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Fig. 1. Location of Wedza District in Mashonaland East Province, Zimbabwe, relative to major urban centres. Wedza Mountain is located in the central part of Wedza District (18°46'28S, 31°32'41E).

agricultural expansion involves numerous conflicts – both social, such as poor recognition of land rights resulting in displacement of rural communities (Cotula et al., 2009), and ecological, such as the situation of much potential agricultural land in highly biodiverse regions (Gibbs et al., 2010). Thirdly, and at a more local scale, rural subsistence livelihoods in Africa are often centred on crop production, livestock rearing, and collection of wild-sourced resources such as firewood and wild foods (Angelsen et al., 2014) and as such are directly linked and highly sensitive to changes in ecosystem properties. Whether approached from ‘bottom-up’ livelihoods and development perspectives or from ‘top-down’ global change and conservation perspectives, understanding the processes and impacts of land use intensification in sub-Saharan Africa is therefore a research priority.

To date there has been little use of HANPP as a land use intensity measure in sub-Saharan Africa. HANPP has been quantified at continental (Fetzel et al., 2016) and regional scales (Abdi et al., 2014), but most national case studies have been carried out in Europe (e.g. Schwarzmüller, 2009; Musel, 2009; Kolheb and Kraussman, 2009) and Asia (Prasad and Badarinh, 2004; Kastner, 2009; Chen et al., 2015), with the only national HANPP case study in Africa focused on South Africa (Niedertscheider et al., 2012). One recent study (Bartels et al., 2017) adapted the HANPP framework to the village scale in Tanzania and calculated village-level HANPP to be between 34 and 38% of annual potential NPP, but without further case studies it is impossible to determine whether this is a representative example. The lack of fine scale HANPP research in Africa may be a consequence of data availability, with commonly used data sets such as FAOSTAT (FAO, 2015a) and the Global Forest Resources Assessment (FAO, 2015b) having well-recognised weaknesses in the African context (Mather, 2005; Fetzel et al., 2016). Previous studies may also have underestimated HANPP in rural Africa due to lack of recognition of the importance of wild-sourced resources such as firewood and construction material in rural livelihoods – a recent global analysis found that around 30% of household

income in rural Africa is derived from such wild-sourced resources (Angelsen et al., 2014), but only a minority of studies have attempted to include domestic fuelwood consumption (Niedertscheider et al., 2012; Fetzel et al., 2016; Bartels et al., 2017), and resources such as construction poles have been largely omitted from existing analyses. Additionally, the low resolution and simplifying assumptions of published studies have potentially obscured important heterogeneity in parameters such as forest structure and population distribution. Drawing linkages between HANPP and ecosystem goods and services such as biodiversity demands a finer resolution of analysis (an approach adopted by Haberl et al., 2004).

Analysis of NPP appropriation patterns at the household scale also has the potential to improve understanding of the social and environmental consequences of changing rural livelihoods. Many studies have documented the income portfolios of rural African households (e.g. Cavendish, 2000; Mamo et al., 2007; Kamanga et al., 2009), but fewer have considered how livelihood strategies and socio-economic characteristics influence household-scale environmental or NPP footprints. Further, past studies indicate that wealthier households have higher absolute environmental income (Cavendish, 2000; Mamo et al., 2007), partly driven by ability to obtain a higher share of the most lucrative environmental resources (Ambrose-Oji, 2003; De Merode et al., 2004), but no research has assessed whether this pattern of ‘elite capture’ of environmental goods is replicated in NPP appropriation, or whether the greater capability of wealthy households to access resources or displace NPP demand during periods of scarcity results in exacerbation of rural NPP appropriation inequalities during land use intensification.

Reflecting the research gaps described above, the first objective of this study is to develop a novel method of quantifying HANPP at the community scale and to calculate HANPP in six villages in central Zimbabwe. Avoiding the inaccuracies associated with the use of national statistics, we instead base our analysis on detailed field data describing woodland structure and rural livelihoods. Our second

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