Socioeconomic drivers of forest loss and fragmentation: A comparison between different land use planning schemes and policy implications

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ABSTRACT

Forest loss and fragmentation, which generate various negative environmental and ecological consequences, have become widespread phenomena across the globe. Motivation to investigate the underlying drivers is essential for land use planning and policy decision making. This paper characterizes forest loss and fragmentation from 1979 to 2014 in the Ningbo region (China) using multitemporal satellite imageries and a set of landscape metrics (area-weighted mean patch area, edge density, area-weighted shape index, Euclidean nearest neighbor distance, effective mesh size and total area); and then quantifies the responsible socioeconomic drivers (economy, social activities, science and technology, culture and policy, demography) under different land use planning schemes (urban and non-urban) using multivariate linear regression. Results show that the two zones present identical trend of intensifying forest loss and fragmentation but differ in changing magnitude and speed. More specifically, forest loss and fragmentation in the non-urban planning zone occurs at a significantly higher pace and magnitude. For the urban planning zone, population pressure, economic growth and fruit consumption are the primary drivers of forest loss, while forest fragmentation is mainly driven by economic openness, cash crop consumption and environmental protection consciousness. For the non-urban planning zone, income increases, fruit consumption and infrastructure development are the primary drivers of forest loss, while infrastructure and tourism development are the major drivers of forest fragmentation. Besides, forest loss and fragmentation in the two zones are both heavily subjected to land use policy. The variance partitioning analysis highlights that the policy driver is the most influential one and economic driver also has strong effect on forest loss and fragmentation in the urban planning zone. For the non-urban planning zone, the influence of policy driver is the strongest and social activity is also very powerful. These results provide compelling evidence that land use planning fails to play an efficient role in protecting forest resources in the Ningbo region. The failure should be attributed to several issues associated with land use planning and forestry governance that widely exist in China. We finally propose some pertinent implications and suggestions for China's land use planning and forest policy. This study is believed to advance the understanding of the socioeconomic drivers of forest loss and fragmentation. It therefore provides some new insights in land use policy.

1. Introduction

As one of the most dominant natural resources on earth, forest covers approximately 4.0×10^7 km^2, accounting for 31% of the global terrestrial surface (FAO, 2012). Forests provide critical social, economic, health and environmental benefits for humankind (FAO, 2012), including timber production, recreation, climate regulation and biodiversity conservation (Gao and Liu, 2011). However, forest ecosystems are highly vulnerable to anthropologic activities, as human society relies on forest resources for all the basic needs, either directly or indirectly (Lele et al., 2008). Many observations highlight that forest ecosystems have been significantly degraded or endangered in many places of the world as a consequence of dramatic human disturbances (Lele et al., 2008; Li et al., 2009; Lambin and Meyfroidt, 2010). The degradations of forest ecosystems are typically related to forest loss and fragmentation (Onojeghuo and Blackburn, 2011). Forest loss refers to the clearing of forests for pasture, harvesting, cultivation or urban development (Gao and
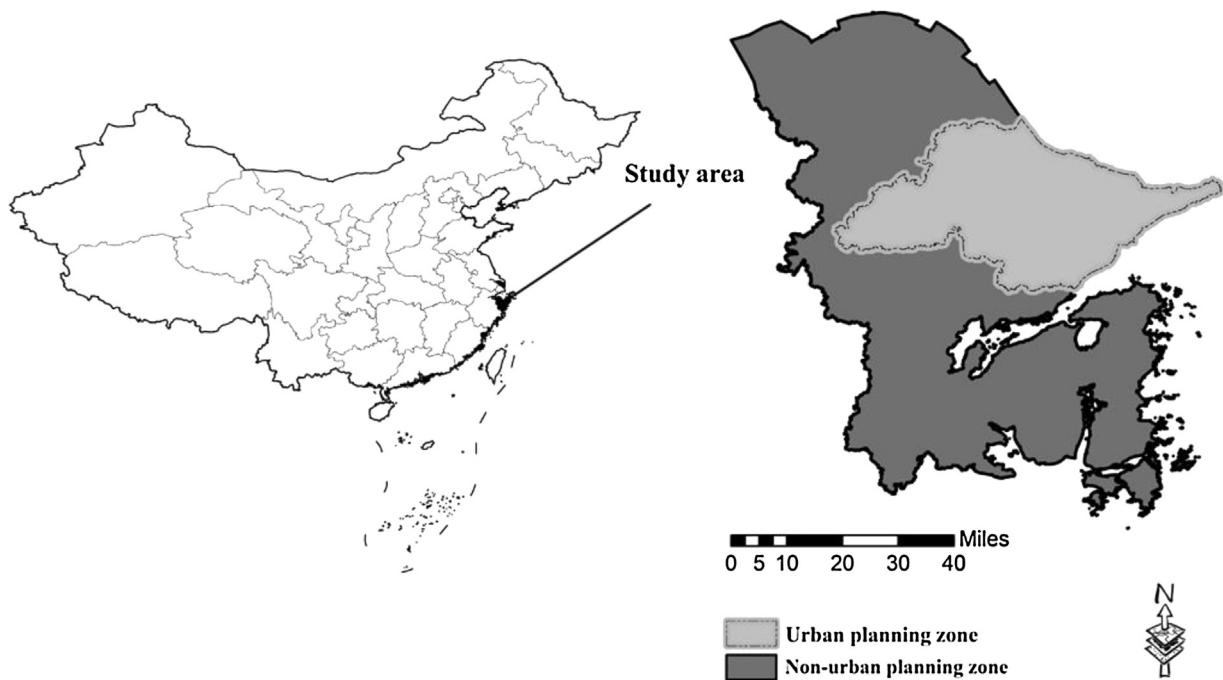
Fig. 1. Geographical site and spatial divisions of land use planning zones in the Ningbo region, China.

Liu, 2011; Miller, 2011). Forest fragmentation refers to the progressive process of subdividing original large and intact forest patches into smaller, isolated and geometrically irregular ones (Echeverria et al., 2008; Lele et al., 2008). Notably, forest loss and fragmentation have various long-lasting and negative environmental and ecological consequences, such as species extinction, water and soil quality degradation, exotic species invasion and sandy storms attack (Carranza et al., 2015; Li et al., 2009; Newman et al., 2014; Tang et al., 2012). It therefore creates high priorities on the agenda of local government in formulating forest protection policy or land use planning (Ewers, 2006; Reddy et al., 2013). In this regard, motivation to investigate the underlying drivers of forest loss and fragmentation is essential for land use planning and policy decision making (Echeverria et al., 2008).

The wording "divers" can be misleading given its dualism. It can either refer to the forcing factors that explain the rooting causes and pressures on the forests, or represent the landscape characteristics or geophysical attributes that determine the occurrence of forest loss and fragmentation (Echeverria et al., 2008). We focus on the former, as recent studies demonstrate that forest loss and fragmentation in rapid developing areas are largely influenced by socioeconomic changes and human demands (Gao and Liu, 2011; Gong et al., 2013; Lambin and Meyfroidt, 2010; Li et al., 2010; van Den Hoek et al., 2014; Zhang et al., 2006), regardless of the variations in geophysical attributes. Also, linking specific landscape changes with certain socioeconomic variables is crucial for developing resource protection practices (Gong et al., 2013; Su et al., 2014a; Xu et al., 2014). Numerous studies have quantified the socioeconomic drivers of landscape pattern changes; however, relatively few studies characterize the influential drivers of forest fragmentation (Gong et al., 2013). Socioeconomic development is heavily influenced by official policy and planning (Abdullah and Nakagoshi, 2007; Xie et al., 2005; van Den Hoek et al., 2014). Therefore, the occurrences of forest loss and fragmentation driven by socioeconomic factors are subjected to land use policy or planning (Abrahams et al., 2015). In this regard, comparing the socioeconomic drivers of forest loss and fragmentation under different land use planning schemes should provide critical references for making

policy and management decisions. Unfortunately, rather few studies have examined the process of forest loss and fragmentation in relation to land use planning.

Forest loss has been the dominant historical land cover change in China (Li et al., 2010). After the 1978s, the whole nation underwent a fundamental transformation from socialism to market economy. The post-socialist cities gradually open the commercial timber markets, resulting in large scale deforestation across the country (Li et al., 2010; Gao and Liu, 2011). The land market reform grants the local government with the authority to approve land use practices (Tao et al., 2010). Many cities experience continuous forest net loss to timber harvesting for agriculture and urban construction (Li et al., 2010). The central committee launches forest policy such as the "Grain for Green" or Sloping Land Conversion Program (SLCP) to restrain forest loss (van Den Hoek et al., 2014). However, the subsequent effect varies with cities and regions given that the implementation effectiveness of the policy is heavily influenced by the local land use planning (van Den Hoek et al., 2014). In particular, land use is under the control of two different planning systems, namely the urban planning and non-urban planning, which lead to the discrepancy in land control (Zhou et al., 2015). Thus, new guidelines are urgently needed to help land use makers to understand the socioeconomic drivers of forest loss and fragmentation between different land use planning zones. However, rather few efforts have been made in this respect.

Satellite imageries, coupled with geographic information systems (GIS), provide cost-effective and timely information in examining the long-term process and pattern of forest cover and landscape development in many different geographic locations (Newman et al., 2014; Li et al., 2009; Tang et al., 2012). Landscape ecological metrics are effective in quantitatively describing the characteristics of forest fragmentation from different aspects (Gong et al., 2013; Lele et al., 2008; Reddy et al., 2013). This paper applies satellite satellite imageries, GIS and landscape metrics into the case of Ningbo region, one of the most forested-cover dominant places experiencing intensive human disturbances in China. We specifically attempt to: (1) characterize the process of forest loss and fragmentation under different land use planning schemes; (2)