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Potential land use adjustment for future climate change adaptation in revegetated regions

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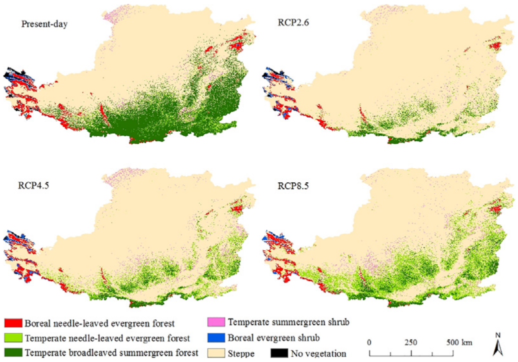
HIGHLIGHTS

- We evaluated the sustainability of current vegetation in China's Loess Plateau.
- Future potential natural vegetation was predicted by a dynamic vegetation model.
- Only 25.3%–55% of forests in 2010 can be kept over 2071–2100 in this region.
- Adjustment of land use pattern is essential to adapt to climate change.

GRAPHICAL ABSTRACT



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ABSTRACT

To adapt to future climate change, appropriate land use patterns are desired. Potential natural vegetation (PNV) emphasizing the dominant role of climate can provide a useful baseline to guide the potential land use adjustment. This work is particularly important for the revegetated regions with intensive human perturbation. However, it has received little attention. This study chose China's Loess Plateau, a typical revegetated region, as an example study area to generate the PNV patterns with high spatial resolution over 2071–2100 with a process-based dynamic vegetation model (LPJ-GUESS), and further investigated the potential land use adjustment through comparing the simulated and observed land use patterns. Compared with 1981–2010, the projected PNV over 2071–2100 would have less forest and more steppe because of drier climate. Subsequently, 25.3–55.0% of the observed forests and 79.3–91.9% of the observed grasslands in 2010 can be kept over 2071–2100, and the rest of the existing forested area and grassland were expected to be more suitable for steppes and forests, respectively. To meet the request of China's Grain for Green Project, 60.9–84.8% of the existing steep farmland could be converted to grassland and the other for forest. Our results highlight the importance in adjusting the existing vegetation pattern to adapt to climate change. The research approach is extendable and provides a framework to evaluate the sustainability of the existing land use pattern under future climate.

1. Introduction

Land use change, due to climate change and human activities, can greatly alter the environment including climate (Pielke, 2005), hydrology (Chen et al., 2015), soil carbon stocks (Deng et al., 2014), and

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primary productivity (Albani et al., 2006), and further brings adverse effects if those changes exceed the environmental carrying capacity of an area. Thus, the consistency of those changes with potential natural vegetation (PNV), dominating by climate and ignoring the impacts of human activities (Chiarucci et al., 2010; Zerbe, 1998), has always been paid great attention. The prerequisite of these studies is to determine the PNV and the extent that the observed pattern overlaps with the NPV, which provides fundamental information to effectively regulate the human activities-induced land use change.

Further, the global warming and increasing carbon dioxide (CO_2) concentration has resulted in large-scale vegetation change across the planet according to those evaluations with the ecosystem models and climate change scenarios on regional and global scales (Hickler et al., 2012; Piao et al., 2006; Piao et al., 2013; Wolf et al., 2008), and it will continue to influence the structure, function, and distribution of vegetation ecosystems in future (Dai et al., 2016; Friend et al., 2014). Can the existing vegetation adapt to future climate change and how will the current land use patterns evolve? Evaluation of this aspect can provide important information for land use management.

This kind of evaluation is especially important for those regions with revegetation programs such as the Grain for Green Project in China (GGP) (Chen et al., 2015), the Bonn Challenge in Germany (Verdone and Seidl, 2017), and the Initiative 20 × 20 launched by Latin American and Caribbean countries (Crouzeilles et al., 2016). With intensive human perturbation, the vegetation in these regions has been experiencing a rapid change. For example, vegetation cover in the key area of GGP has almost doubled between 1999 and 2013 according to satellite imagery (Chen et al., 2015), and the Bonn Challenge launched in 2011 plans to restore 350 million ha of degraded forest landscapes by 2030 (Verdone and Seidl, 2017). These programs are implemented according to some criteria; for example, the GGP in China requires farmlands with slopes >25° to be returned to grasslands or forests. With intensive perturbation in a short period, the ability of the land use pattern to adapt to future climate change should be further investigated.

China's Loess Plateau (CLP), located in the middle reach of the Yellow River (Fig. 1), is one of the most severely eroded areas in the world (Zhao et al., 2013). It was, therefore, chosen as the pilot region for the GGP in 1999 (Li et al., 2017). Subsequently, the change speeds of the normalized difference vegetation index over 2000–2015 were ten times of those in 1982–1999, among which human activities account for 55% of the change (Li et al., 2017). The GGP has effectively controlled soil erosion, and erosion levels have returned to historic values (Wang et al., 2016a). Despite this success, the revegetation program is approaching its water resource limits on CLP (Feng et al., 2016). Chen et al. (2015) argued that the revegetated area should be maintained, but not expanded further as originally planned. With substantial land use change and subsequent environmental changes, CLP has become an ideal area to investigate land use change and its environmental effects.

In this study, we used LPJ-GUESS (Smith et al., 2001; Smith et al., 2014), a process-based dynamic vegetation model, to simulate high-resolution PNV for the current time period and a future time period. We then compared the land use pattern from the PNV simulation with the land use pattern observed on CLP to investigate whether the current human-induced land use pattern is consistent with the future PNV and present information for land use adjustment under future climate.

2. Materials and methods

2.1. Study area

CLP has an area of 6.2×10^5 km^2. With an arid to sub-humid climate, the mean annual precipitation ranges from 96.1 to 1469.5 mm, and the mean annual temperature has a range of −8.9 to 14.7 °C (1960–2000) (Chinese National Ecosystem Research Network, 2017). The annual mean precipitation and temperature decrease from the southeast to the northwest. Compared with 1981–2010, the annual mean precipitation and temperature would increase during 2071–2100 (Peng et al., 2018). However, the change will vary with the intensity of radiative forcing, i.e. Representative Concentration Pathway (RCP). Different greenhouse gas concentration trajectories predict different changes in precipitation and temperature (Fig. 2): a 6% increase in precipitation and a 1.5 °C increase in temperature under RCP2.6, 12% and 2.3 °C under RCP4.5, and 22% and 4.3 °C under RCP8.5.

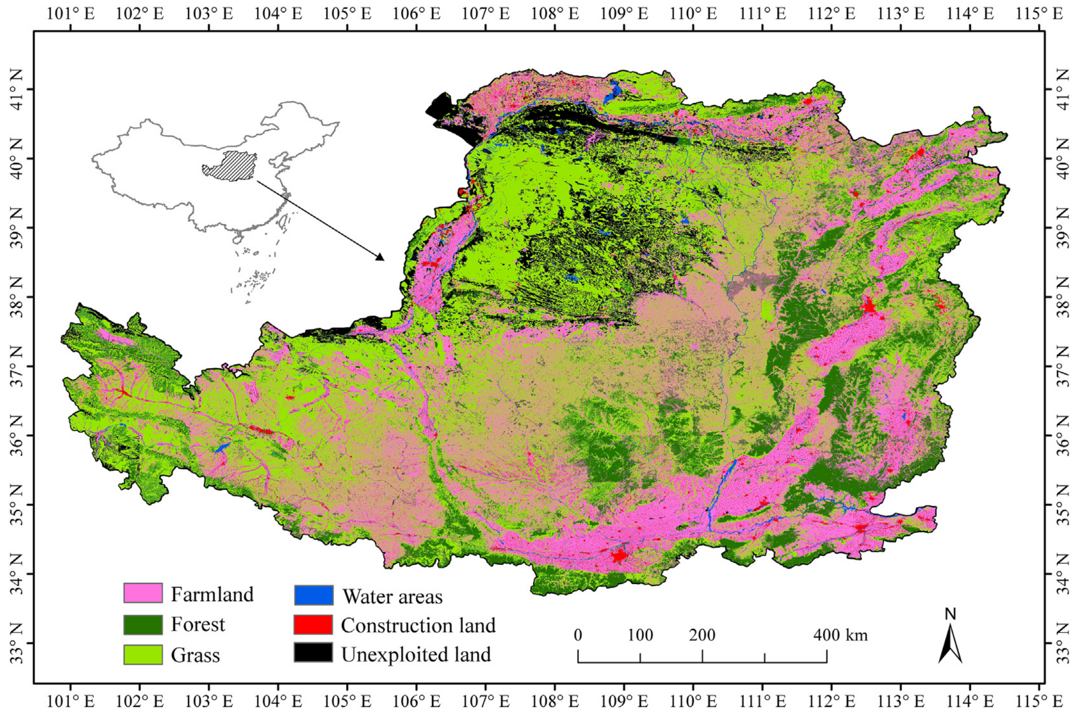

Fig. 1. Location of China's Loess Plateau and its land use in 2010 (Li et al., 2016).