Title: The Social and Environmental Dimensions of China's Spatial Planning System

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Abstract: Decades of double-digit economic growth make China the fastest expanding major economy in history while saddling the country with likely the most severe environmental crisis faced by any civilization. Senior leaders of the People's Republic of China (PRC) are realizing to tackle this massive problem they must transform China's development model. The PRC is embarking on its most ambitious reforms on sustainable development in the nation's history. These are featured in the recent 13th Five-Year Plan (2016-2020) with increased investments of over $1 trillion US dollars in environmental protection. The main macro-level policy is a national zoning plan using environmental limits to strategically plan economic growth. The political objective is to protect vital ecosystem services to construct an ecological civilization to obtain "harmony between humans and nature." For the past decade, China has been working to coordinate regional development using four functional zones: (1) optimal development (urban agglomerations to drive its high-tech, green transition); (2) priority development (fast growing urban and industrial centers); (3) restricted development (agricultural and ecological function zones for food security and ecosystem services); (4) prohibited development (ecological zones, ecological redlines, national parks, cultural heritage sites, etc.). The major innovation and centerpiece is designating "ecological function zones" and "ecological redlines" across the country to restrict development in accordance to regional carrying capacities.

Despite the enormous scale and importance of the changes underway, China's spatial planning system is poorly understood by the international community. This is resulting in minimal discussion on the concepts and actions being taken that have serious implications for both China and the world. In this paper, we present the key components of China's spatial planning system. We review the current literature on the preliminary environmental and social outcomes from 2010-2017. We found China's development pattern for optimal and priority zones is following the spatial planning system, but the rate of growth remains too high for restricted zones. Simultaneously ecosystem area and quality for forests, grasslands, and shrublands have improved since 2000, however the overall quality of China's ecosystems remain low. Lastly, the ecological compensation payments, financial compensation to landholders for foregoing development activities, are improving public services and rural incomes, but remain insufficient for restricting development. We conclude with lessons learned and major challenges to date on balancing large-scale ecosystem protection, competitiveness, and poverty alleviation.

Keywords: spatial planning, ecological civilization, green growth, ecosystem services, distributional impacts

Themes: A. Competitiveness impacts of environmental policies; B. Distributional consequences of environmental policies; E. Sectoral/structural transition management

Introduction

Unprecedented economic growth has improved human welfare for decades, mainly at the expense of the environment, however environmental damages have reached a scale where they are now considered serious threats to human welfare and future prosperity. The conventional modernization approach where countries first invest in economic growth then environmental protection has increased incomes and resolved local pollution problems. However countries are facing more complex, simultaneous environmental challenges than the past. There is growing scientific evidence that current patterns of growth and consumption are unsustainable, which is impacting development prospects and progress on human welfare indicators (IPCC, 2014; MA, 2005; OECD, 2011; US NRC, 1999; World Bank, 2012). Ecologists define environmental limits for humanity as carrying capacities (Arrow et al., 1995). A carrying capacity is the population of humans that can be supported by an ecosystem at a given level of consumption under a given technological capacity (Daly & Farley, 2004). Passing carrying capacities can cause dramatic alterations in ecosystem functions, which can lead to social-ecological collapse (Cumming & Peterson, 2017). Therefore despite its successes, the current economic system is threatening the ability of ecosystems to provide the necessary goods and services (e.g., food, pollution removal, flood protection) to sustain economic activity and human welfare (Daly & Farley, 2004).The Millennium Ecosystem Assessment (2005) estimates that approximately 60% of the world's ecosystem services (i.e., the benefits society obtains from ecosystems) are now at a lower quality than 50 years ago. This decline in ecosystem services is causing increased scarcity in fundamental resources like fertile soil and water (UN WWAP, 2017). Humanity has entered a new era where risks to development are rising as growth continues to erode our natural capital.

In particular, developing countries must manage *local* (e.g., sanitation problems), *regional* (e.g., water scarcity), and *global* (e.g., climate change) environmental problems at lower income levels than developed nations during their industrialization (Bai, 2007; Marcotullio et al., 2005). Nowhere is this compression in environmental stages more apparent than China. China has the second largest economy in the world, yet it remains a developing country due to its relatively low per capita income ($8,123 USD in 2017) (World Bank, 2017). Even if China's growth slows as projected, China will become a high-income country before 2030, but its per capita income will remain far lower than high-income nations (WDRC, 2013). China's rapid growth rate, large population, and geography (nearly 30% of its land area is desert) have likely caused it to experience broader, more severe environmental burdens at a lower income level than other nations. China is either near or has crossed regional carrying capacities (Zhang et al., 2016). Scientists estimate that more than 85% of China's provinces are experiencing ecological deficits where demand for ecosystem services exceeds ecological supply (Zhao et al., 2015). China's pattern of development has led to severe resource shortages, ecological damage, and pollution. Over half of Chinese cities lack sufficient water supplies, and 46% of all lakes and reservoirs experience toxic algae blooms (Liu & Raven, 2010). In 2016, 75% of Chinese cities failed to meet the national ambient air quality standard (MEP, 2016). Air pollution is estimated to cause one out of every five deaths in China, equating to approximately 4,000 fatalities each day (Rohde & Muller, 2015). Once thresholds are crossed finding ways to regain ecosystem services is quite challenging (Zhang et al., 2016). China must transform its development model hence the Chinese government is pioneering steps on implementing green growth policies.

China is the first major economy to pursue green growth at a national scale using a comprehensive governance strategy known as the construction of an "ecological civilization." The objective is to respect environmental limits by enhancing and sustaining ecosystem services to create a society where there is "harmony between humanity and nature." Chinese institutions are pursuing a series of major reforms, spanning ecological protection, restoration, pollution control, efficient resource use, and recycling. The centerpiece of the governance strategy is establishing a national spatial planning system using *major function zones* to guide economic development (State Council, 2010). Establishing a coordinated governance system on land-use (e.g., zoning, pollution control, finance, and monitoring) is considered to be the most important institutional mechanism for constructing China's ecological civilization (State Council, 2015). Land-use planning is concerned with the intensity, form, amount, and harmonization of land development for different social functions: housing, industry, recreation, transport, education, nature, agriculture, and cultural activities (Albrechts, 2004). In 2010, the People's Republic of China (PRC) State Council selected four development zones to coordinate various functions (Fan et al., 2010; State Council, 2010): (1) optimal and (2) priority development zones for urban and industrial functions; (3) restricted development zones for agricultural and ecological functions; (4) prohibited development zones for ecological and cultural functions. Land-use planning in Europe and the United States often focuses on the municipality with no formal recognition of ecosystem functions or ecosystem services (Albrechts, 2004; Dale et al., 2000). China is the first country to design and institute a nationwide spatial plan on enhancing ecosystem functions for vital ecosystem services (Ouyang et al., 2009; Xu et al., 2017). China is attempting to address the root cause of its complex web of socio-ecological problems, uncontrolled development, to meet three objectives: (1) sustainability, (2) competitiveness, and (3) poverty alleviation. China's spatial planning system illustrates a possible means for addressing the Sustainable Development Goals under the UN's Agenda 2030.

In this paper we present the principal components of China's spatial planning system, and evaluate environmental outcomes relative to impacts on competitiveness and poverty alleviation. We reviewed the literature on major function zones to assess preliminary environmental and social outcomes from 2010-2017. We discuss current challenges on balancing sustainability, competitiveness, and poverty alleviation. We conclude with lessons learned from China's recent experience on trying to achieve significant environmental improvements while simultaneously enhancing competitiveness and poverty alleviation.

China's spatial planning system

Until the past decade, China's spatial planning and regional development strategy has always emphasized economic development where local governments saw the Gross Domestic Product (GDP) growth rate as the main objective. China's approach has led to great achievements, but also serious problems, such as development disparities, uncontrollable urbanization, ecosystem degradation, and biodiversity loss. Since the economic reforms the urban-rural income and regional development gaps have grown. China has one of the world's highest levels of income inequality in the world. In 2008, the income of urban residents in coastal provinces was 1.4 times greater than inland provinces, and 1.6 times greater than rural residents (Fan et al., 2010). China's average Gini coefficient from 2003-2014 was 0.48, which is 58% higher than European nations and 13% higher than the United States (Han et al., 2016). Furthermore the majority of impoverished regions tend to be regions with minority ethnic groups and fragile ecological environments (i.e., highly degraded ecosystems). In 2011, 245 of the 592 national-level poverty counties (41%) were minority and ecologically fragile (Fan et al., 2012). Furthermore land use efficiency has declined while development intensity and urbanization have grown exponentially. Fan et al. (2010) found that the development intensity of several provinces and cities in China can be as high as 40%, which far exceeds that of developed countries like Japan and Germany who are between 5-11%. The lack of strategic planning has led to significant losses in cultivated lands and ecosystems, creating concerns on food and ecological security across China. Inefficient resource use, pollution, and ecological disasters undermine China's global competiveness. Economists estimate environmental costs accounted for 9% of China's Gross National Income in 2008, almost four times more than the United States and nine times greater than Japan (WDRC, 2013).

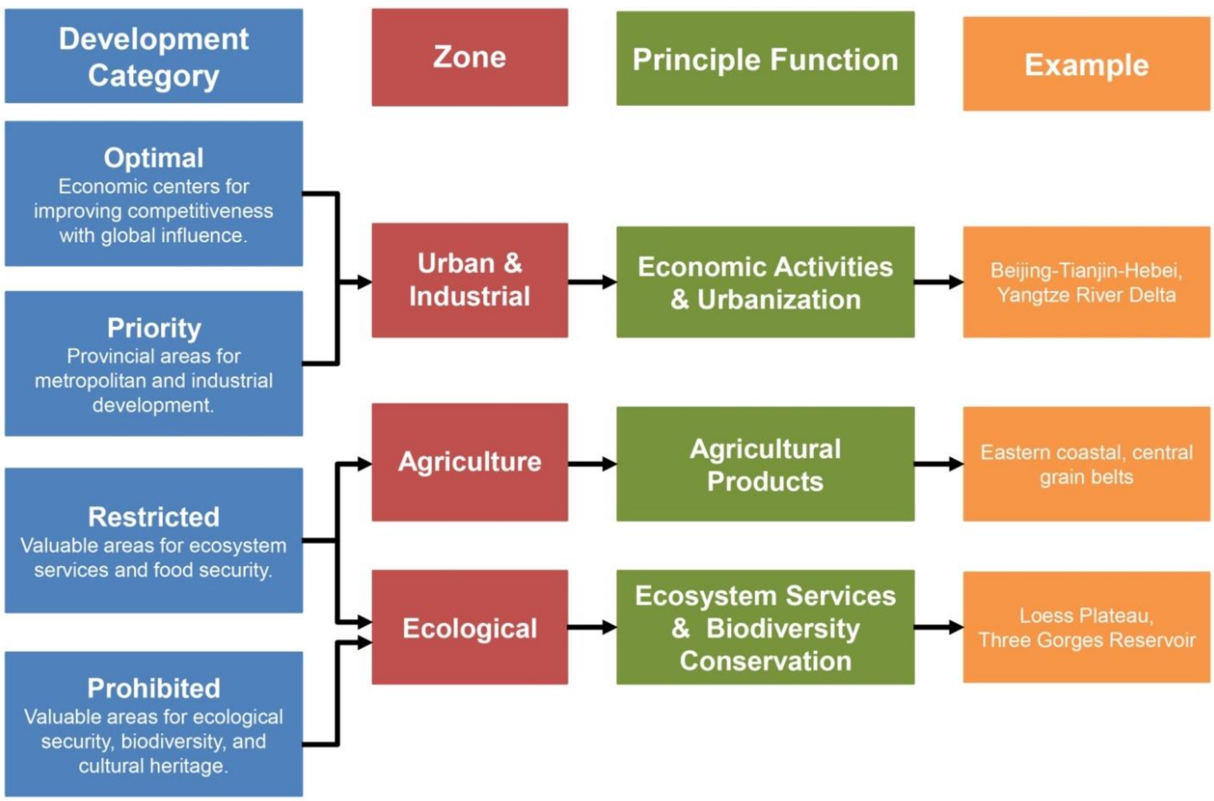

Figure 1. Conceptual diagram of the four development zones in China (1) optimal development and (2) priority development zones for urban and industrial functions; (3) restricted development zones for agriculture and ecological functions; (4) prohibited development (priority conservation areas) for ecological and cultural heritage functions.

China has been working to establish a spatial planning system to achieve wise development practices that sustain vital ecosystem services, reduce development disparities, and promote economic competitiveness. In 2010, the State Council published the *National Plan on Major Function Zones*, which was subsequently upgraded to the *Major Function Zone Strategy* published in the 12th Five-Year Plan (2011-2015). President Xi Jinping and the Central Committee of the Communist Party refer to the spatial planning system as the *major function zone system* or *functional zoning strategy*. The spatial planning system consists of four development categories for different social and ecological functions (Figure 1). First are optimal development zones, which are major urban and industrial centers (i.e., megalopolises or megaregions). The main function is developing China's high-tech, green development transition through smart urban planning. The objective is to optimize development by focusing on efficient use of resources via low-carbon, circular economy practices and development efficiency. The Central Government sees optimal development zones as global centers of commerce and finance, such as the Yangtze River Economic Belt, Pearl River Delta, Beijing-Tianjin-Hebei Region, and Bohai Rim. Second are priority development zones selected to help reduce development disparities between coastal regions and central and western China. These areas are in the early stages of industrialization, such as the middle reaches of the Yangtze River, central and southern Hebei, and the Central Plains. Third are restricted development zones where moderate development is allowed to ensure the protection of agricultural and ecological functions. These areas include major grain and crop producing counties as well as ecosystem service hotspots and fragile ecosystems. For the ecological function zones (EFZs) the primary task is to restore degraded ecosystems. Scientists selected these areas because they are deemed vital for national food and ecological security. Fourth are prohibited development zones to guarantee the protection of natural and cultural heritage sites where development is forbidden. These areas are EFZs encompassing nature reserves, national parks, national scenic spots, ecological redline areas, etc.

EFZs are selected using two primary criteria: ecological vulnerability (ecosystem areas close to tipping points; high degradation) and ecological importance (high source areas of ecosystem services and biodiversity). The Central Government selected key EFZs for five ecosystem services: (1) water retention; (2) biodiversity protection; (3) soil retention; (4) sandstorm fixation; (5) flood mitigation (Figure 2). In 2010, the State Council selected 25 key EFZs, which were updated in 2015 to 63 key EFZs (MEP, 2015). The Ministry of Environmental Protection (MEP) and the Chinese Academy of Sciences (CAS) updated the EFZs using scientific information from China's first National Ecosystem Assessment (2000-2010) led by the Research Center for Eco-Environmental Sciences, CAS (Ouyang et al., 2016). In total, the EFZs now cover approximately 49.4% of China's land area (4.74 million km^2), providing approximately 78% of China's carbon sequestration services, 75% of soil conservation services, 61% of sandstorm prevention services, 71% of water resource conservation services, 60% of flood mitigation services, and 68% of natural habitat for biodiversity. These ecosystems represent important watersheds, forests, grasslands, and species habitat (Ouyang et al., 2016). Marine EFZs have also been designated, but they are not included in this review.

Ecological redlines are the legal mechanism for safeguarding essential ecological areas in EFZs. Ecological redlines are regulatory targets defined as the minimum ecological area needed to guarantee and maintain ecological functionality and biological diversity for national security. Ecological redlines are the strictest designation on ecosystem protection where ecosystem areas cannot decrease, they can only increase overtime. Ecological redlines unlike EFZs have legal status under the revised Environmental Protection Law (2014) thereby elevating the importance of EFZs with prohibited development status. In 2013, President Xi vowed "China set and strictly observe an ecological redline which requires all regions to optimize, prioritize, restrict or prohibit their industrial development according to their defined nature." Ecological redlines are considered China's "bottom line" and "lifeline". Currently all governments (municipal and provincial) are drawing their ecological redlines using EFZ boundaries as guidelines. The goal is to establish ecological redlines by the end of 2020, and formulate a complete governance system by 2030.

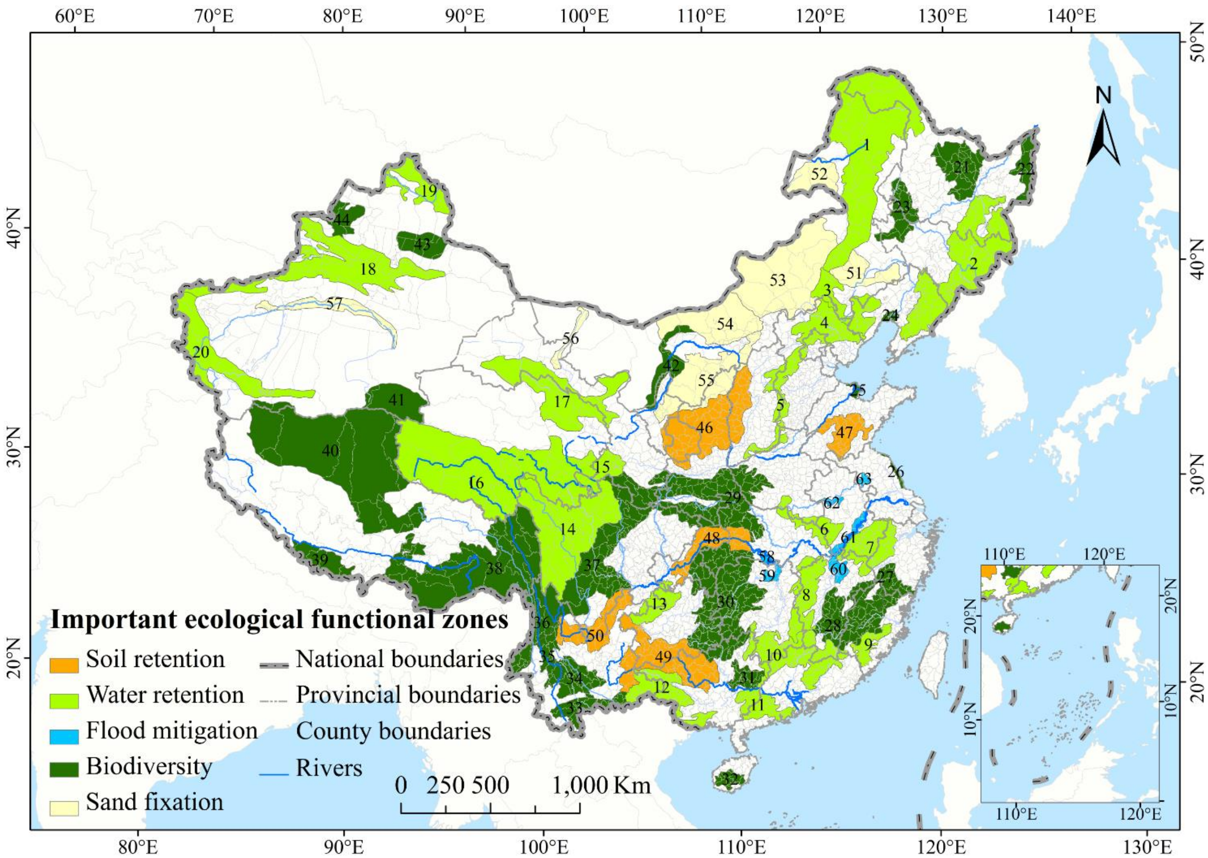

Figure 2. Sixty three national key ecological function zones published by China's Ministry of Environmental Protection (2015) grouped by ecosystem service.

Ecological transfer payments

The Central Government established ecological transfer payments to incentivize local communities (i.e., suppliers of ecosystem services) to protect EFZs and ecological redlines for the selected ecosystem services. The Central Government began experimenting with ecological transfer payments in 2008, starting with 6 billion RMB (904 million US; 1 USD ~ 6.63 RMB) distributed across 200 counties. Since the inception of the program, investments and the number of counties are growing every year. In 2016 the Ministry of Finance issued approximately 60 billion RMB (9.04 billion USD) to over 700 counties. To date the Central Government has spent over 300 billion RMB (45 billion USD) on ecological transfer payments. The funds are used to promote sustainable social and economic development by enhancing: (1) ecological protection and (2) basic public services (e.g., education and healthcare). Ecological transfer payments are now the largest ecological compensation program in terms of investment and scope in China (Sun & Lu, 2015).

Allocation is determined by the Central Government who distributes the funds to provinces containing EFZs. Provinces subsequently distribute the funds to respective municipalities and counties within EFZ boundaries. Local governments should use the funds to curb ecological degradation in various ways: (a) compensating communities for foregoing industrial and development activities; (b) supporting national nature reserves and national parks; (c) funding ecological engineering and restoration projects; (d) funding the recruitment and salaries of rangers to protect ecological function areas; (e) enacting pollution reduction and mitigation measures. Depending on the development condition of the counties, the funds can also be used to enhance public services, such as access to public education and improving medical services. Local government performance is evaluated annually to determine whether payments will be reduced or enhanced. The MEP created a set of indicators known as the county-level environment index (EI). The EI indicators should be tailored to the particular region and EFZs. The EI indicators consist of ecosystem structure, environmental quality, and ecosystem service indicators. The Central Government set a threshold level where the ecological environment should not fall below 2009 levels. For regions where ecosystem area and quality continue to deteriorate then 20% of the transfer payment is suspended until the EI improves. For counties where ecosystems deteriorate for three consecutive years, the transfer payments are suspended for the following year. Payments are not reissued until the EI is restored to the pre-2009 level.

Environmental impacts

Environmental impacts from the functional zones cannot be evaluated in isolation from other major conservation programs in China since they are working in tandem (Huang et al., 2018). China first established 16 large-scale terrestrial conservation programs prior to the spatial planning system, which has improved ecosystem area and quality across China. Total investment in these 16 programs is 378.5 billion USD from 1978-2015 (Bryan et al., 2018). Ouyang et al. (2016) present the main findings from China's first National Ecosystem Assessment (2000-2010). They evaluated the effectiveness of China's conservation programs, prior to the establishment of EFZs and ecological redlines. Ouyang et al. (2016) determined China's national conservation policies significantly improved ecosystem quality over the past decade. Six ecosystem services increased from 2000-2010: food production (38%), carbon sequestration (23%), soil retention (13%), flood mitigation (13%), sandstorm prevention (6%), and water retention (4%), whereas habitat for biodiversity decreased (–3%). Restoration greatly increased forests (41,330 km^2), shrubs (9,111 km^2) and grasslands (21,103 km^2), mainly in the Loess Plateau and mountainous areas in southern China. However when considering ecosystem increases relative to losses, the net ecosystem increase is small (only covering 1,700 km^2). Furthermore, the overall ecological quality of forests, shrubs, and grasslands remain low. Multiple socio-ecological policies (e.g. development, conservation, agricultural, etc.) are acting with no coordination, which is leading to tradeoffs across societal needs. China's conservation policies have led to ecological improvements compared to the previous decade, but currently these efforts remain insufficient for raising the majority of China's ecosystems from "degraded" to "high quality" (i.e., favorable functioning for multiple ecosystem services). Hence the Central Government is pursuing spatial planning to integrate the environment into development to elevate the prominence of conservation.

Scientists are starting to evaluate the preliminary environmental outcomes of the EFZs using government statistics on EI and development area from 2010-2015. Sun & Lu (2015) evaluate the percent change in EI of participating counties from 2010-2012 and 2012-2014 where $\Delta EI>1$ is "ecological environment improves"; $\Delta EI = 1$ is "stable ecological environment"; $\Delta EI <1$ is "ecological environment declines". From 2010-2012, they found that counties with ecological environments graded as "improve" accounted for 6.9% of the 466 counties; "stable" accounted for 91.1%; "decline" accounted for 2%. From 2012-2014, they found that 14% of the 512 counties were graded as "improve", 72.2% were "stable", and 13.8% were "decline." The number of counties has been increasing each year, thus the percent change in EI offers a general assessment of the environmental status. These preliminary evaluations provide only a limited picture since the time-series is short, and scientists should compare EI changes in the same counties since 2009. Overall current statistics suggest the ecology in the EFZs is stable, and a comparable proportion of EFZs are experiencing improvements and declines.

Alternatively development rates continue to grow faster than desired in optimal development zones and restricted development, agricultural and ecological function zones. Liu et al. (2017) and Ning et al. (2018) assessed the development rates and development intensities in the major function zones. First constructed lands in China increased by approximately 24,600 km^2 from 2010-2015, and 43% of the increase occurred in western China, primarily from cropland conversion. The majority of the expansion in constructed lands occurred in the priority development zones, following the pattern outlined in the national spatial plan (Ning et al., 2018). Liu et al. (2017) compared the development rates and development intensities before the establishment of functional zones (2000-2010) and after (2010-2013). The annual development rate decreased significantly in optimal zones, but increased significantly for priority zones, agricultural and ecological function zones (Figure 3). The urbanization process in optimal zones is changing from simple ad-hoc urban expansion to optimization of urban form. Urbanization rates are growing faster in priority zones to increase modernization in central and western China. Lastly, the rate of change and intensity of urbanization and industrialization in agricultural and key ecological function zones is lower in the last five years compared to 2000-2010. However overall the growth rates remain too excessive, and are not in line with restricted development.

Lastly the Central Government wants to integrate industrial policy into the spatial planning system where water use, coal use, and other toxics are regulated to ensure the protection of ecological function areas. Provincial governments should work with municipal and county-level governments to generate clear guidelines on industrial restrictions in EFZs. The State Council is asking governments to generate a list outlining restrictions known as the "negative list for industry access", and regular inspections will be conducted in EFZs. Guangdong Province, the leading exporter in China, is one of the first province's to publish its list on industrial restrictions. On May 2017, the Development and Reform Commission of Guangdong Province released its *Negative List of Industrial Access to National Key Ecological Functional Zones in Guangdong Province (Pilot)* for eleven counties within the boundaries of key EFZs (Lechang, Nanxiong, Ruyuan, Shixing, Renhua, Longchuan, Heping, Lianping, Jiaoling, Pingyuan and Xingning). These include designated areas of the agriculture sectors (e.g., forestry, animal husbandry and fisheries), manufacturing, wholesale and retail factories, and mining. Ultimately China wants to develop circular economy practices to reduce pollutant discharge and foster clean production standards in papermaking, printing and dyeing, chemical, building material, and tanning industries.

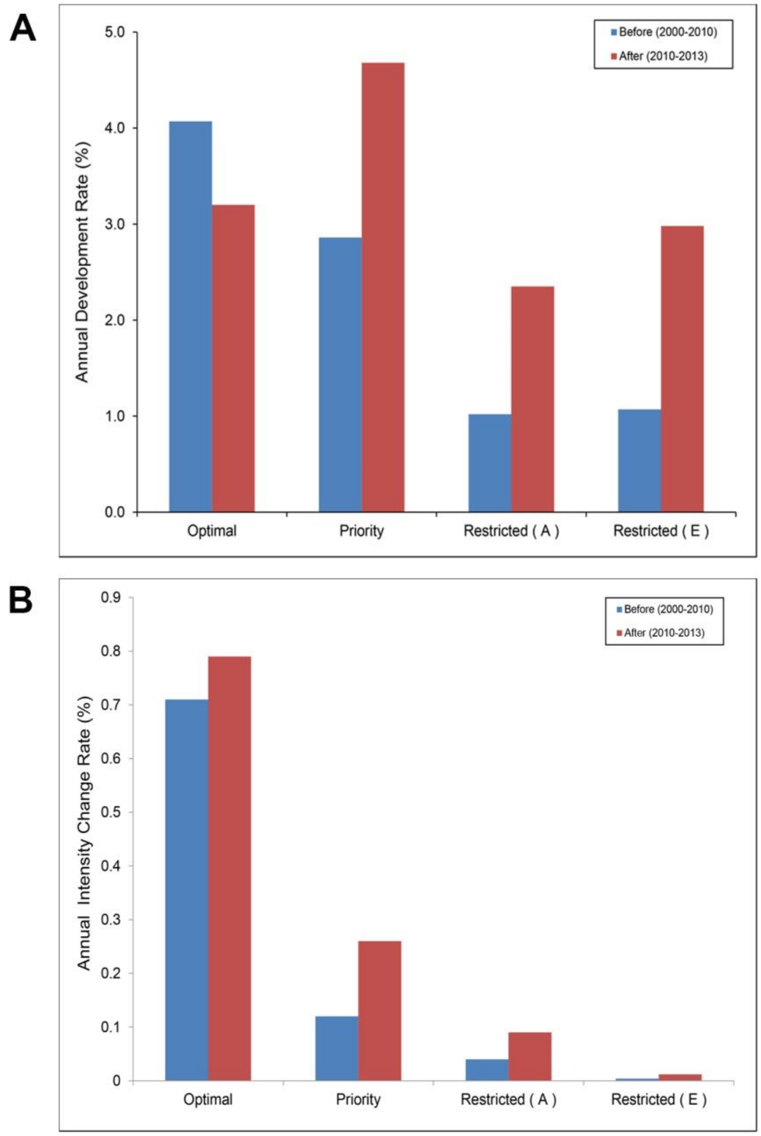

Figure 3. Annual percent changes of (a) development area and (b) development intensity before (2000-2010) and after (2010-2013) the implementation of the spatial planning governance system. Development intensity is the percent change in the total area of constructed lands in the study area (10 x 10 km). Note: Restricted (A) is restricted zones for agricultural functions, and Restricted (E) is restricted zones for ecological functions (Liu et al., 2017).

Competitiveness & distributional impacts

The spatial planning system aims to reduce economic and social tradeoffs associated with conventional development practices by improving the quality and efficiency of development in optimized and priority zones. The spatial planning system outlines the future division of China's land area as follows: 15% is urbanization areas with 55% of the population; 26% is food security areas with 30% of the population; 59% is ecological security areas with 15% of the population (Fan, 2015). Currently the majority of the population resides in eastern and southern China (Figure 4) where the largest cities are located. Furthermore most of the country's GDP is generated along the east coast (Bohai Rim, Shanghai, and Pearl River Delta), resulting in substantial development disparities between eastern and southern China and western and central China (Figure 5). The Central Government is using priority zones to try to reduce development disparities (evident in Figures 4-5) by investing in urbanization and industrialization in western and central China. China is also trying to rectify its competitiveness gap with high income nations by optimizing development in the Pearl River Delta Region and Yangtze River Economic Belt. If China is able to successfully develop high-tech, green industries it could become a global leader in new markets like renewable energy technologies and less resource intensive manufacturing. China is also striving for efficient, dense urban living to sustain its fragile ecosystems. China has been experimenting with eco-city and low-carbon designs to improve human health and quality of life while reducing ecological footprints (De Jong et al., 2016).

Alternatively concentrating economic development in optimized and priority development regions may exacerbate regional disparities (Figure 5), if Chinese institutions fail to provide sufficient support to rural communities on employment and public services. Ecological compensation is considered by most experts as the most important institutional mechanism for promoting sustainability and the ecological civilization in China (Xie et al., 2015). In our literature review we found no direct analysis of the impacts of China's spatial planning system on competitiveness and poverty alleviation. However we draw from China's experience on ecological compensation to assess the potential benefits and challenges associated with establishing EFZs and ecological redlines using ecological transfer payments.

Overall ecological compensation via direct payments to local communities for the provision of ecosystem services has led to poverty reduction and ecological improvements in China (Bryan et al., 2018; Liu et al., 2008). One of the most studied examples is China's Sloping Land Conversion Program (SLCP), which is one of the longest running and largest payment for ecosystem services (PES) programs in the world. The SLCP is a cropland conversion program where farmers are given grain and cash subsidies to convert cropland on steep slopes to forests and grasslands. From 2000-2013, the Central Government invested over 354.2 billion RMB (56 billion USD) in afforestation of the Yangtze and Yellow River Basins, resulting in 31.8 million hectares of new forests. The State Forestry Administration estimates that SLCP payments account for 14% of mean per capita income of enrolled households, and poverty incidence decreased from 36% in 1998 to 6.6% in 2011 (IIED, 2017). The SLCP is helping diversify livelihoods by shifting households from farming to other economic activities, such as construction, transportation, businesses, etc. However there are certain cases where farmers, pastoralists, and forest workers report adverse impacts on their livelihoods due to logging and grazing bans, and inadequate compensation for lost wages.

Lastly we present the types of supporting financial and capacity building policies undergoing development for reducing negative impacts on competitiveness and incomes associated with EFZs. On July 2018, the State Council published a comprehensive report on the social and economic impacts from ecological transfer payments in the Qinghai-Tibet Plateau. This region covers the entire Tibet Autonomous Region, Qinghai Province, and portions of Sichuan, Yunnan, Gansu, and Xinjiang Provinces (total area is 2.6 million km^2 with average altitude of more than 4,000 m above sea level). Its glaciers, lakes, and wetlands form one of the most important water sources in the world since they comprise the headwaters of China's three major rivers: Yangtze, Yellow and Lancang Rivers. The Central Government is implementing several conservation programs, including ecological transfer payments to protect and restore key

EFZs. From 2008-2017, the Central Government made transfer payments of 16.29 billion RMB (2.46 billion USD) in Qinghai and 8.35 billion RMB (1.26 billion USD) in Tibet to protect key EFZs across 77 counties.

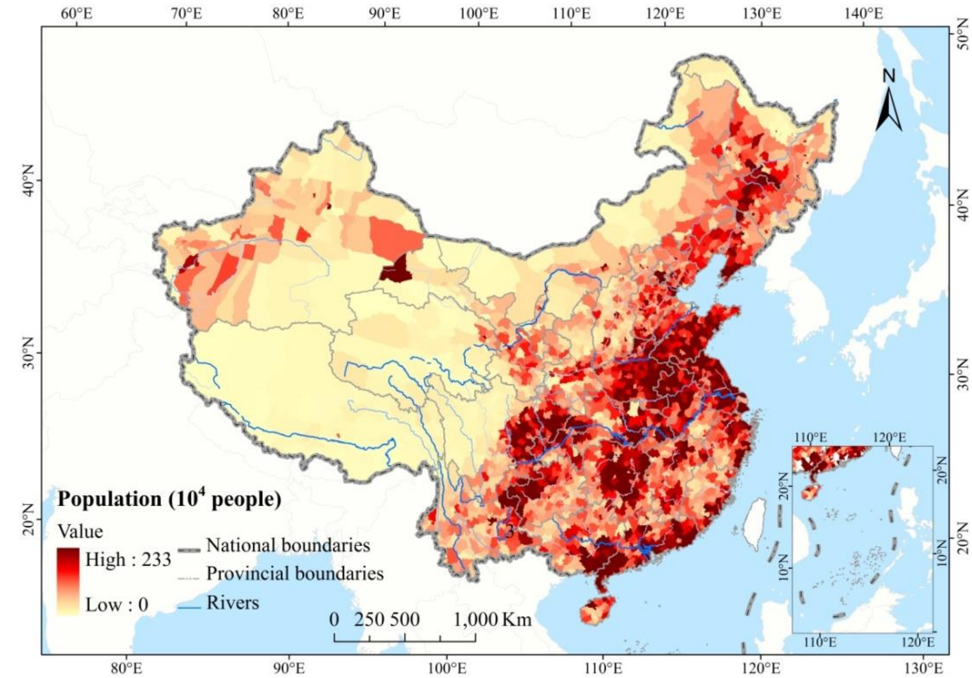

Figure 4. Mean annual population per county from 2010-2015.

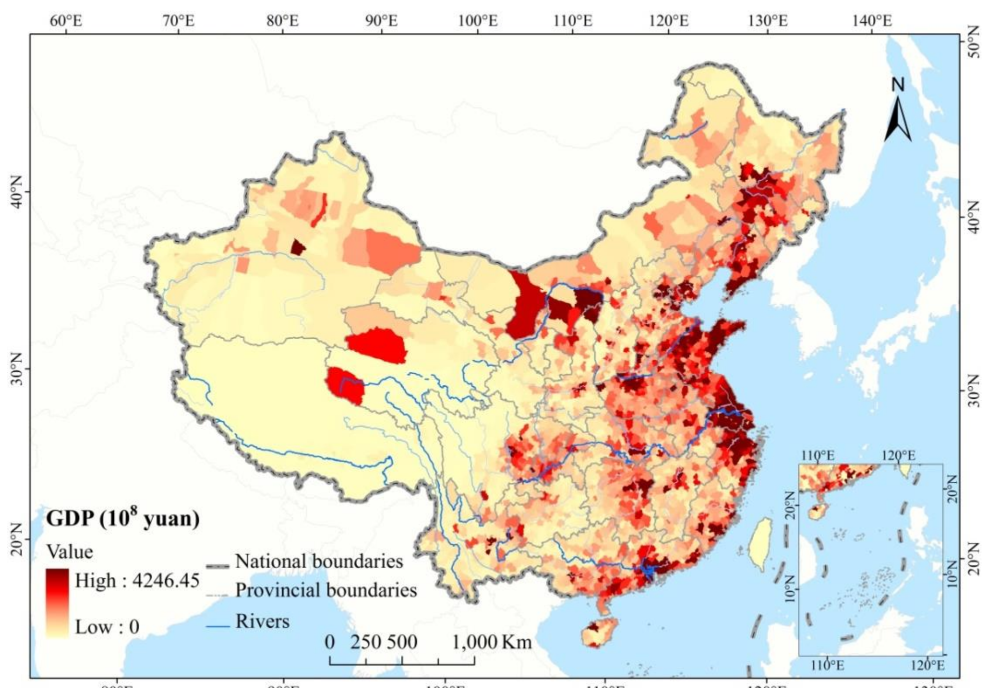

Figure 5. Mean annual gross domestic product (GDP) per county from 2010-2015.

Local governments are experimenting with a diversity of projects for trying to improve forests, grasslands, biodiversity, and poverty reduction. Ecological projects include: (1) returning grazing lands to grasslands; (2) returning farmland to forests (grasslands); (3) controlling desertification; (4) wetland ecosystem protection; (5) forest and grass fire prevention; (6) soil and water conservation; (7) construction of protected area management facilities; (8) capacity building. In conjunction with these ecological projects are human welfare projects: (1) construction of small towns; (2) livestock support; (3) energy infrastructure; (4) drinking water projects; (5) waste disposal and sewage treatment. Since 2011, local governments have used the funds to provide housing to 622,300 rural households in Qinghai. Also state funds have been used to improve infrastructure to make clean drinking water accessible to over 1.6 million people and electricity available to 650,000 people. Investments have also dramatically improved forests, wetlands, grasslands, and wildlife populations. Per capita income has grown because of improvements in grassland productivity and ecological subsidies. In 2016, per capita net income of farmers and herdsmen reached 7,300 RMB (1,158 USD) with an average annual growth rate of 12%. Lastly the Qinghai-Tibet Plateau is trying to become an economic model of circular economy and renewable energy practices on green development. The Central Government has established two national circular economy pilot parks in Qinghai Province: Qaidam Circular Economy Pilot Area and Xining Economic and Technological Development Zone. Since 2004, more than 3 billion RMB (452 million USD) was invested in Tibet to fund more than 450 projects unique to the region, including highland barley, yak-breeding, and traditional Tibetan medicine. More than 100 enterprises have been established to help increase and diversify incomes of local farmers and herdsmen. On average income levels have increased significantly because of ecological compensation, infrastructure construction, and local development of animal husbandry and tourism industries.

Discussion

We conclude with lessons learned and major challenges to date on balancing large-scale ecosystem protection, competitiveness, and poverty alleviation. From China's experience on land conservation, we are learning large-scale projects can foster marginal improvements, but our institutions must coordinate efforts across natural resource protection, pollution control, and economic development. China has spent hundreds of billions of dollars on conservation making it one of the largest investors in ecosystem services worldwide (Salzman et al., 2018). However overall the majority of China's ecosystems remain low quality, and despite the successes, the trend on ecological degradation has yet to be reversed. Simply the lack of coordination has led to minimal progress on curbing the reduction of ecosystem services and biodiversity worldwide. Even if we have substantial political will like in China, we are learning first-hand the difficulties of restoring and rebuilding degraded ecosystems at scale. It takes strong governance to build the required coordination and commitment to sustain efforts overtime to allow ecosystems to recover. The magnitude of China's environmental crisis necessitates comprehensive solutions, given the interconnected nature of its social-ecological challenges. The spatial planning system is a bold, innovative governance approach for tackling the root problem - mismanagement of ecosystems at the landscape-level. No country has attempted to implement a coordinated plan on ecosystem functionality for goods and services at a national-scale (Ouyang et al., 2009; Ouyang et al., 2016). To date ecosystem management, ecosystem services, and carrying capacities have remained mainly theoretical with minimal policy application. China is challenging traditional development practices by making these concepts guiding principles in its governance strategy on green growth, known as the construction of an “ecological civilization.”

China is still in the pilot phase on dividing the country into different development and ecological function zones. The preliminary land-use and land-cover results suggest China’s development pattern is following the guidelines of the optimal and priority zones. However controlling development rates in restricted and prohibited zones are problematic. The governance challenge is obtaining political legitimacy on EFZs and ecological redlines from local governments, industries, and communities. To date the EFZs remain mainly theoretical with minimal on the ground implementation (CCICED, 2014). Simply few governments want their land-uses under the strict requirements of EFZs and ecological redlines. The Central Government has been trying to slow China’s economic growth rate, however many cities and provinces are growing faster than the target level evident in the high development rates in restricted zones. Controlling development and prioritizing ecosystem protection will take time and substantial governance. Institutions across China are working to enhance scientific and management capacities on monitoring, valuing, and assessing ecosystem services. Worldwide we lack scientific and management standards on ecosystem services.

However we are seeing promising progress when Chinese institutions develop coupled ecological-social programs, making the three objectives joint goals: (1) sustainability, (2) competitiveness, and (3) poverty alleviation. China’s joint programs on ecosystem restoration, employment, infrastructure, health services, and education are helping to break the vicious cycle of ecological degradation and poverty (Bryan et al., 2018). In particular ecological compensation is helping the poorest communities in China obtain essential public services like medical treatment, clean water, electricity, and education. The difficulty for local governments has been balancing the use of ecological payments for ecosystem protection (restoration) and public services. Currently the payments are often insufficient to meet both needs simultaneously. Hence Chinese experts suggest institutions diversify funding streams using market-based mechanisms. There are many beneficiaries from the ecological payments, such as hydropower plants, municipalities and businesses downstream from EFZs, etc. China’s experience on ecological compensation illustrates how PES can help minimize impacts on competitiveness while reducing disparities to advance large-scale ecosystem protection.

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