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National assessment report on policy related to Natural Capital Accounting in China

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Contents

Abstract

To address the severe environmental crisis, policymakers in China are constructing a new governance strategy with major reforms across all social sectors to better balance development with ecological protection. It seeks to promote environmental quality and human livelihoods by enhancing and sustaining natural capital (ecological assets and ecosystem services). The first step is the national wide ecosystem survey and assessment. The second step maps the services, identifying the crucial areas for ecosystem service provision. The third step is how to translate this into practical and effective policies, such as ecological functional zoning, ecological compensation, ecological restoration, and Gross Ecosystem Product (GEP) accounting. There are four key lessons can be drawn from China's efforts to enhance green growth: match the ecological problem orientation with ecosystem service science, establish the sustainable supply of ecosystem services as a national goal, mainstream ecosystem services through policy innovation and financial mechanisms, and requirement of new policy mechanism to engage local residents and other stakeholders in conservation policy making and implementation.

1. Preface and background

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. China's ecosystems are quite fragile due to severe land degradation, erosion, desertification, water scarcity, and pollution. Ecological threats continue to grow in scale and severity across China because of rapid urbanization and increased consumption of natural resources (Bryan, et al, 2018). Wildlife habitat has declined, causing substantial losses in biodiversity, and poor air and water quality are causing human health problems. Political recognition of China's crisis started in 1998 when deforestation and erosion caused massive flooding along the Yangtze River. The floods killed thousands of people, made over 13.2 million people homeless, and cost US$36 billion in property damage.

Faced to these serious eco-environmental problems, Chinese government recognizes that China must change its development model from unbounded growth to respecting environmental limits. President Xi and China's State Council are envisioning a new pathway forward, known as the creation of an *Ecological Civilization*. The aim is to improve livelihoods by achieving harmony between humanity and nature. The Ecological Civilization is not simply a philosophical vision of social development. Policymakers are constructing a new governance strategy, with major reforms across all social sectors to better balance development with ecological protection. The Ecological Civilization captures China's approach to inclusive, green growth. It seeks to promote environmental quality and human livelihoods by enhancing and sustaining natural capital.

2. National ecological policy priorities related to sustainable development and environmental conservation

Natural capital management is a national priority for China, hence China has quickly become a leader in four core areas on ecosystem services: (1) natural capital accounting (e.g. survey & assessment, gross ecosystem product); (2) national zoning (e.g. ecological function zones, ecological redlines); (3) financial mechanisms (e.g. ecological compensation); (4) ecological

restoration and engineering (Fig 1).

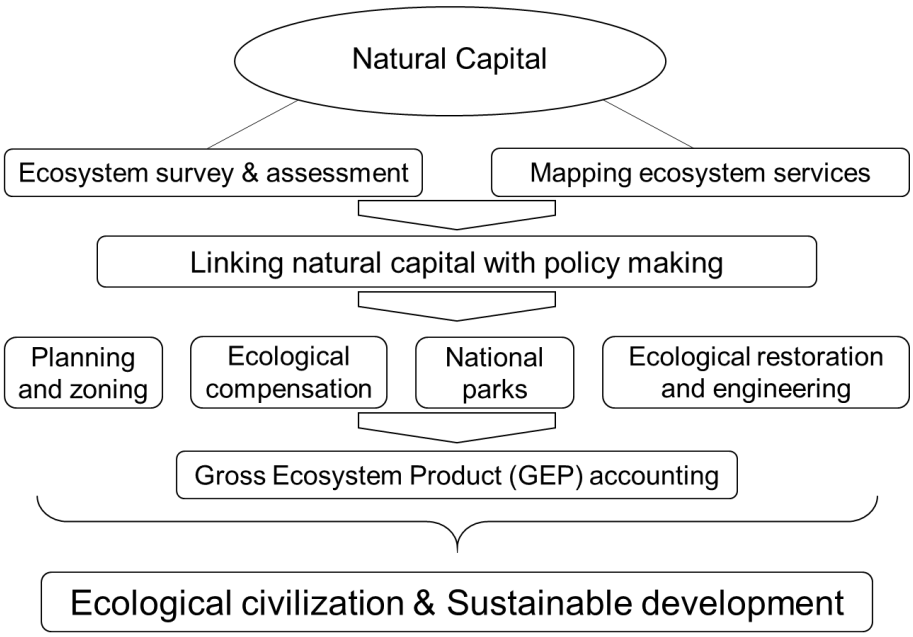

Fig 1. National ecological policy priorities related to sustainable development and environmental conservation

Developing new policy mechanisms to improve environmental governance requires a strong scientific foundation. The first step is the national wide ecosystem survey and assessment (Fig 2). The second step maps the services, identifying the crucial areas for ecosystem service provision and exactly where protection is needed (Ouyang, et al, 2016; Fig 3 A-H). The third step addresses how best to secure ecosystem services and evaluate the effectiveness of their provision. And the last step is how to translate this into practical and effective policies.

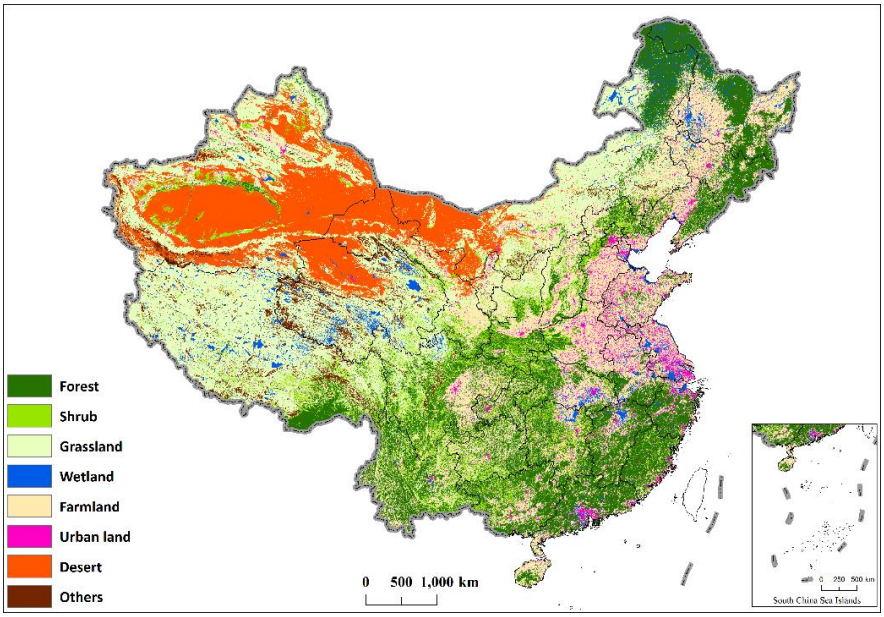

Fig 2. Ecosystem spatial pattern across China

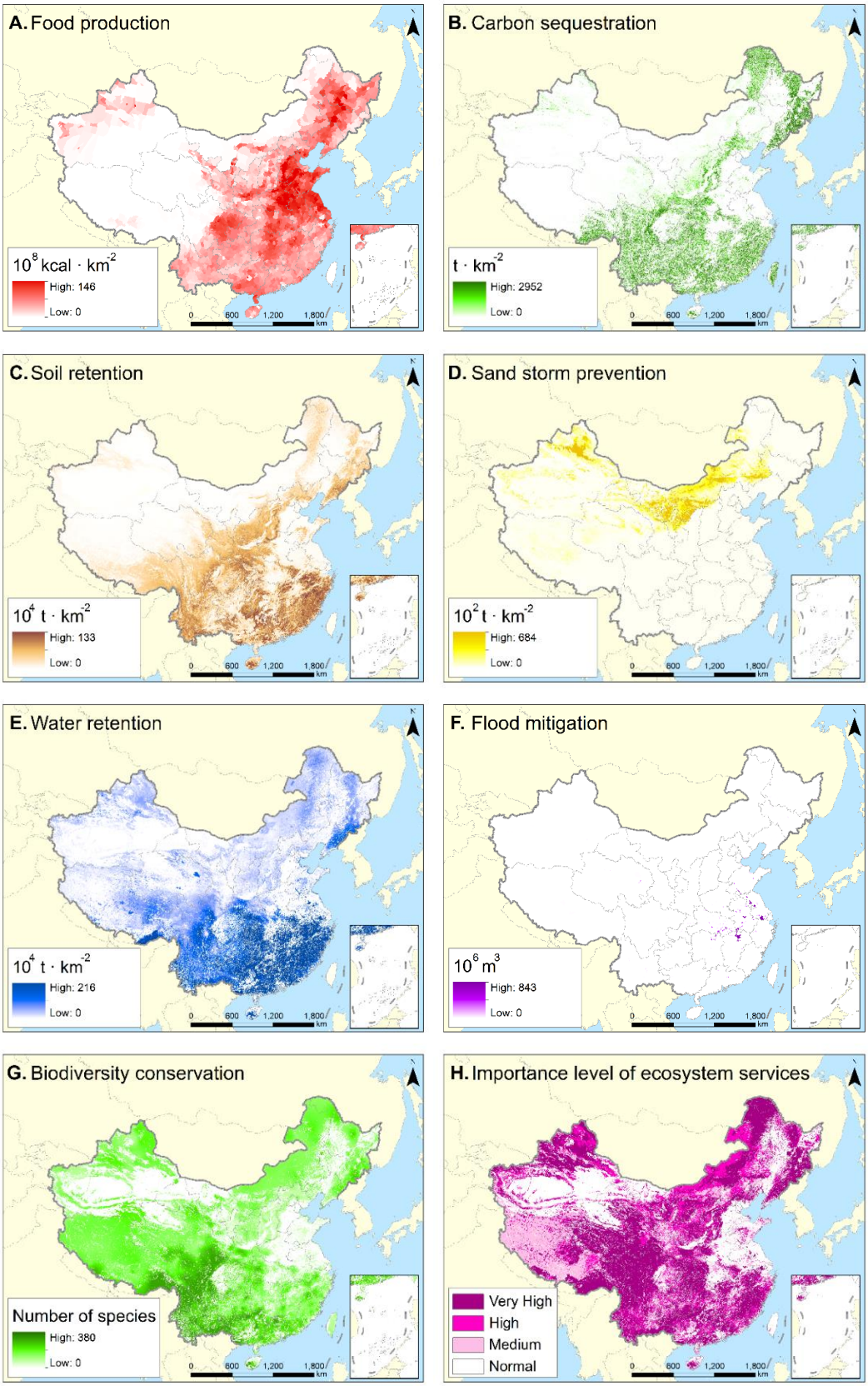

Fig 3. China ecosystem services spatial pattern. (A) Food production (10^8 kcal km^{-2}); (B) Carbon sequestration (t km^{-2}); (C) Soil retention (10^4t km^{-2}); (D) Sandstorm prevention (10^2 t km^{-2}); (E) Water retention (10^4t km^{-2}). (F) Flood mitigation (10^6m^3) (G) Provision of habitat for biodiversity (total species richness of endemic, endangered, and nationally protected species per county) (H) Index of relative importance of ecosystem services

In the past decade, it is estimated that the total change in ecosystem area is 195,803 km^2, which is approximately 2% of China's total land area. The largest increases are in urban areas and forests, and largest decreases are in agricultural lands. The principal ecosystem types converted to cities were: agricultural lands (76%), grasslands (8%), forests (5%), and wetlands (5%). Overall China's national conservation policies significantly improved ecosystem quality from the past decade. 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.

Six ecosystem services increased since 2000. Food production had the largest increase (38%) followed by carbon sequestration (23%), soil retention (13%), flood mitigation (13%), sandstorm prevention (6%), and water retention (4%), whereas habitat provision for biodiversity decreased (–3%). From ecosystem service maps, we identify key hotspots for ecosystem services provisioning to determine priority ecological areas for spatial planning. Nationally, we estimate the priority areas are providing approximately 83% of China's carbon sequestration services, 78% of soil retention services, 59% of sandstorm prevention services, 80% of water retention services, and 56% of natural habitat for biodiversity, although they make up only 37% of China's terrestrial area.

Based on these scientific assessment results, the central government and local governments have developed a series of strategies on mainstreaming the protection of ecosystem services using national zoning, ecological compensation, national parks, ecological restoration (engineering), and gross ecosystem product (GEP) accounting for building the ecological civilization.

2.1 Planning and zoning

Building Key Ecological Function Zones (KEFZs)

In 2008, the MEP and CAS released the national Ecological Function Zoning (EFZ) Plan, which was compiled over four years across fourteen government departments. In 2015, the MEP and CAS revised the EFZs on the basis of China's Ecosystem Assessment. The central government selected 63 key EFZs (KEFZs) from EFZ to protect and sustain five ecosystem services: (1) water retention; (2) biodiversity protection; (3) soil retention; (4) sandstorm fixation; (5) flood mitigation (Table 1; Fig 4). In total, KEFZs 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, 61% 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.

Table 1. Key ecological function zones (KEFZs)

Functions	Number of Zones	Area ($x10^3 km^2$)
Water retention	20	2,035.6
Biodiversity protection	24	1,743.1
Soil retention	5	393.1
Sandstorm prevention	7	530.5
Flood mitigation	6	38.1

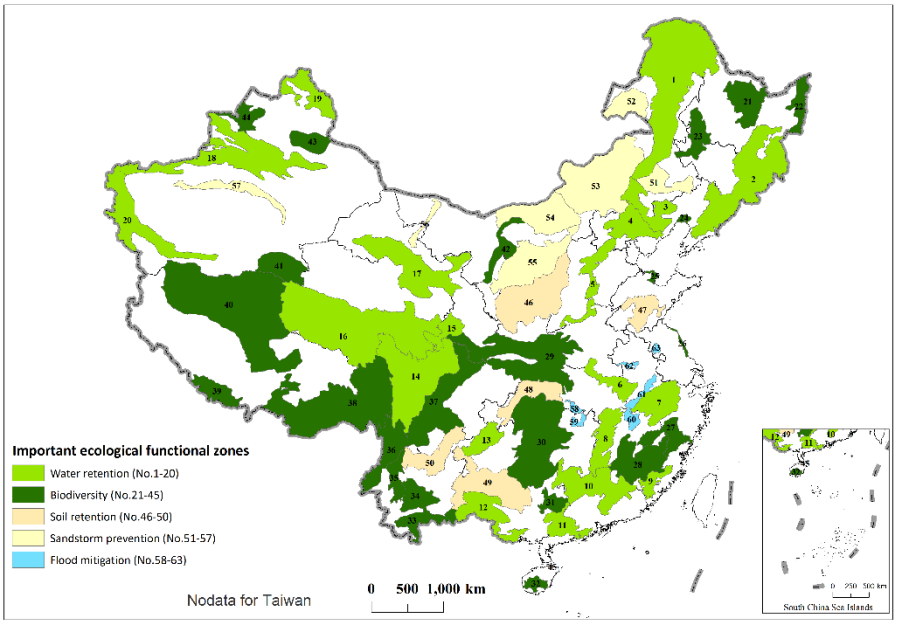

Fig 4. Distribution of key ecological function zonings

The central government is using the 63 key EFZs to determine the location of the urban/industrial and agricultural zones to control development (Johnson, 2017). The Major Function Oriented Zoning Plan illustrates (Fig 5) how the key EFZs aim to guide development of different land-uses to attempt to implement strategic spatial planning. Lastly, China's National Development Reform Commission has down-scaled the key EFZs to determine county-administrative boundaries for ecological transfer payments, resulting in a total of 676 EFZs at the local level.

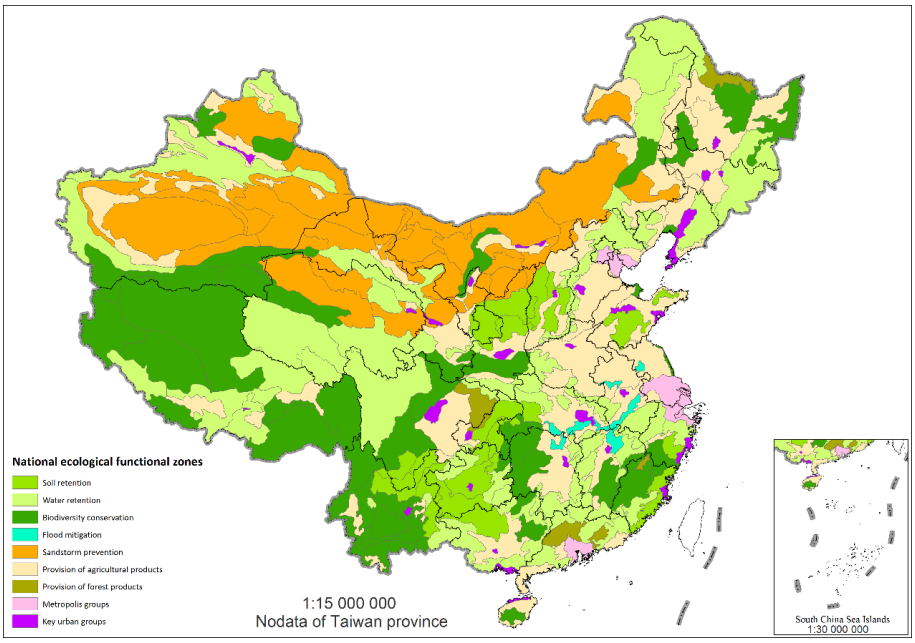

Fig 5. Major function oriented zoning

The United Nation's Environment Program (2016) has described Major Function Oriented Zoning as a core innovation in China's new governance approach. For the first time, a major economy has designated "main functional areas" to "manage spatial use in accordance with the major ecological conditions of different localities."

Ecological redlines

EFZs represent the technical criteria on ecosystem protection; however policymakers need a legal mechanism for integrating these critical ecosystems into management systems (CCICED, 2014). Chinese policymakers have been using redlines as “bottom-line” targets for arable land, marine ecosystems, and forests for decades (Lü et al., 2013). Individual redlines, however, have led to fragmentation creating conflicts between government authorities, thus the new Ecological Redline Policy aims to unify different environmental and biological targets in order to move China towards coordinated management. In 2013, the CPC vowed that China will establish and observe ecological redlines to control development. Senior leaders consider ecological redlines central to achieving China’s ecological civilization (Zheng and Ouyang, 2014). Ecological redlines are defined as the designation and enforcement of regulatory targets on ecosystem area to guarantee and maintain ecological safety and functionality, and biological diversity for national security, sustainable development, and human health (Bai et al., 2016; China MEP, 2017).

In 2015 ecological redlines gained official legal status in China’s revised Environmental Protection Law. To date ecological redlines are the strictest legal targets on ecosystem protection where no development is prohibited. The current procedures for delineating ecological redlines represent a combination of top-down and bottom-up procedures. For municipal and provincial governments to select ecological redlines they should conduct ecological assessments considering three criteria: (1) ecosystem services, (2) ecological sensitive areas, and (3) biodiversity conservation (China MEE, 2017).

In 2017, the CPC and State Council stated governments must determine the exact boundaries of ecological redline areas by 2020 to formulate the national governance system. Currently all municipalities and provinces are delineating their respective redlines using national EFZs and local conditions to formulate regulatory targets. The National Ecosystem Assessment is informing the national ecological redline target and sub-level targets.

2.2 Initiating ecological transfer payment and a series of eco-compensation policies

Ecological transfer payment

Another major barrier limiting ecosystem protection is the lack of finance mechanisms to incentivize and compensate communities for foregoing development activities. As noted above, currently the largest ecological compensation program in terms of investment, scope, and objectives is the program known as ecological transfer payments to implement key EFZs. 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. The number of participating counties and financial investments are growing every year (Table 2). To date, the central government spent over 300 billion RMB (45 billion USD) to more than 700 counties on ecological transfer payments. The funding level is determined at the county-level, considering population size, ecosystem types, spatial scale of key EFZs, GDP, mean income levels, ecological restoration projects, etc. The central government sums the calculated costs across the counties and cities in the given province. Next the Ministry of Finance transfers the funds to the provincial finance department who in accordance with local conditions formulates a transfer payment method to the municipalities and counties in the key EFZs. The provincial government is responsible for effective fund

allocation and supervision of activities. The central government with relevant departments regularly assesses the distribution and use of payments to monitor the effectiveness of fund transfers between different levels of government.

Table 2. Subsidies granted by the Central Government to key ecological function zones

Year	Central government subsidies to key ecological function zones (Billion RMB)	Number of counties
2008	6	230
2010	25	451
2012	37	466
2014	48	512
2016	59	600+
2017	62.7	700+

The funds are used to promote sustainable social and economic development by supporting two major activities, the enhancement of (1) ecological restoration protection, and (2) basic public services (e.g., education and healthcare).The central government also regularly monitors local government performance in terms of fiscal responsibility, ecosystem services, water quality, public services, and poverty alleviation efforts. This determines whether payments will be reduced or enhanced. In regions where ecosystem services and quality continue to deteriorate, then 20 percent of the transfer payment is suspended until they are improved. For counties where ecosystems deteriorate for three consecutive years, the transfer payments are suspended for the following year. Payments do not resume until ecosystem services and water quality are restored to the pre-2009 level.

Other eco-compensation policies

In China ecological compensation is seen as a favorable policy mechanism for reducing poverty while encouraging ecosystem protection. Ecological compensation attempts to reduce conflicts between development and conservation by having beneficiaries (i.e. urban residents) pay suppliers (i.e. rural farmers) to protect ecosystems for specific services like maintaining clean drinking water. At present, besides the Ecological Transfer Payment, China's ecological compensation policies mainly include: the Sloping Land Conversion program, Natural Forest Protection project, Ecological Forest Compensation, Ecological Transfer Payments for EFZs, Grazing Land to Grassland program, Grassland Ecological Protection subsidies, Wetland Eco-Compensation and some regional cooperation projects.

Likely one of China’s most famous ecological compensation programs is the Sloping Land Conversion program. Since 2013 the Central Government has invested over 354.2 billion RMB (55.5 billion USD), resulting in the afforestation of 477 million mu of land. In this program the state subsidizes living expenses and grains and seedlings, if farmers return farmland to forests. To date over 32 million farmers and 124 million workers in 2,279 counties have participated in the program thereby making it one of the largest conservation programs in the world (Liu et al., 2008).

Paddy Land to Dry Land Program in Miyun Reservoir is one successful case of regional cooperation projects (Zheng et al., 2013). In 2006, Beijing at downstream of Miyun Reservoir signed a “rice-to-dryland conversion” agreement with upstream Chengde and Zhangjiakou Municipalities in Hebei Province. Beijing agreed to pay an average of 450 RMB per mu (~US$844 per ha in 2006); 15 mu = 1 ha and 8 RMB = US$1 in 2006 per year for land that

was converted from rice to dryland cultivation, with payments adjusted to reflect market land-use values. In 2008, the Beijing government increased compensation to 550 RMB per mu (~US$1173 per ha in 2008) per year to ensure participation would not reduce household incomes. In practice the main land-use conversion was farmers switching from growing rice to growing corn. By 2010, upstream households in the Miyun Reservoir Watershed had converted all rice fields to dry land crops (total area = 103,000 mu). The PLDL program has improved water provisioning and water purification services.

2.3 Proposing national parks

National parks are regions with strict protection and management of the authenticity and integrity of nationally representative natural ecosystems, natural landscapes, and habitats of rare and endangered wildlife, with the purpose of leaving precious natural heritage for future generations. National parks have four features: 1) National park is one type of protected areas, and the main component of the national protected area system; 2) The major target of national park is the protection of nationally representative ecosystems and natural landscape; 3) National park protects the integrity of ecosystem structure, process, and function; 4) National park incorporates public welfare, developing eco-education and eco-tourism under a conservation priority.

Adopting the layer-scoring method, the selection indicators are divided into three layers with a total of 100 points: the first layer is national representative (35 points); the second layer includes authenticity (15 points) and integrity (15 points); the third layer includes importance of ecological location (9 points), historic and cultural value (8 points), urgency (8 points), feasibility (5 points), and anti-interference (5 points). The national park candidates must meet the following conditions: 1) The total score is not less than 75 points; 2) The first layer score is not less than 25 points; 3) The second layer score is not less than 20 points. National park potential areas are to be scored according to the national park evaluation criteria and sorted according to the scores in eco-geographic regions, with each eco-geographic region containing at least one national park. Based on the above criteria, 84 national park candidates are proposed, including 76 terrestrials and 8 marines (Fig.6).

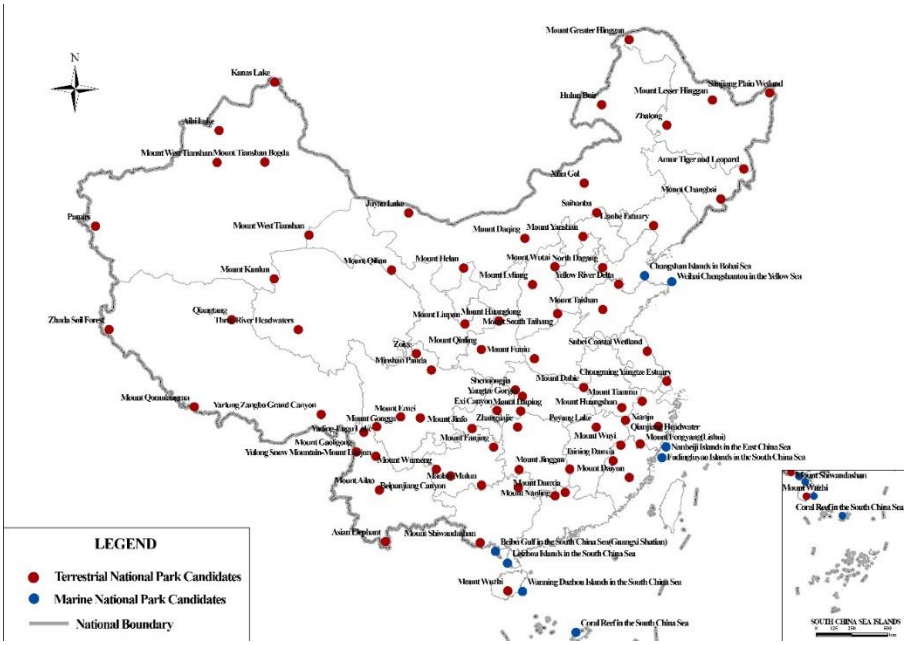

Fig.6 Spatial Distribution of National Park Candidates

2.4 Creating ecological restoration and engineering

China’s degraded ecosystems now dominate the national landscape. Hence the Chinese Government has been trying to restore or ecologically engineer degraded systems to enhance ecosystem services. The central government has created a wide range of national and regional restoration programs, such as Grain to Green Program, Sanjiangyuan Nature Reserve in Qinghai Province, Beijing-Tianjin Sandstorm Control Program, Three-North Shelterbelt, Eco-environmental Protection and Comprehensive Management Program of Qilian Mountains, Yangtze River Shelter Forests, Eco-environmental Protection and Comprehensive Management Program of Qinghai Lake, Integrated Management of Rocky Desertification in Karst Regions, and so forth. While some of these programs also receive ecological compensation as discussed above, the main goal of these programs has been to restore degraded ecosystems (Fig 7; Shao et al.,). Here we will introduce two cases.

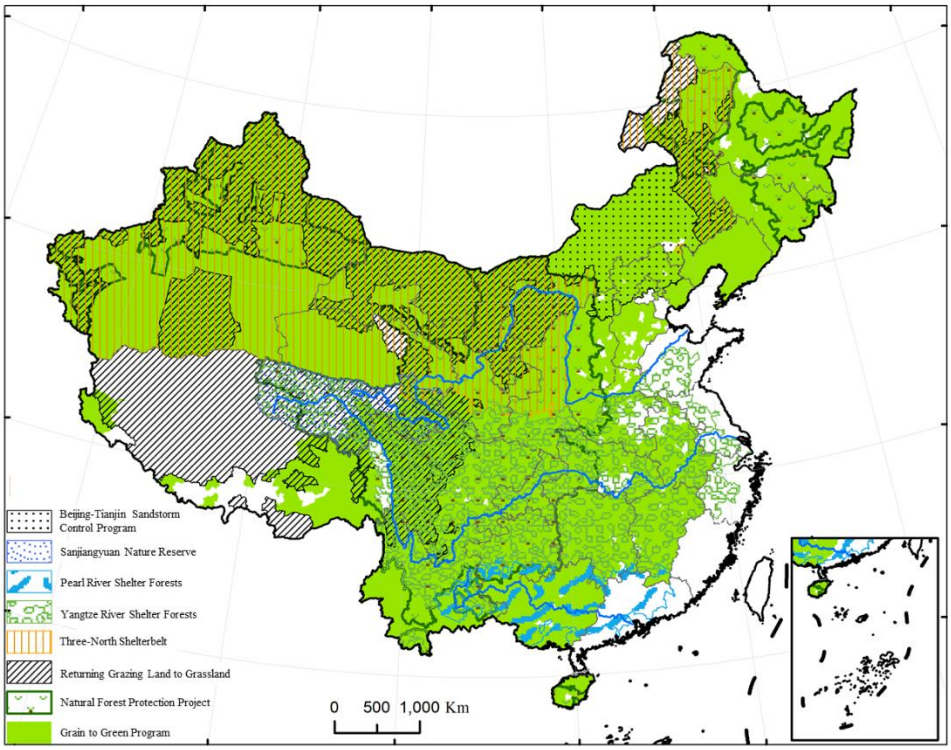

Fig 7. Distribution of ecological restoration and engineering

China mainly implemented NFPP in the upper reaches of the Yangtze River and the upper and middle reaches of the Yellow River, as well as NFPP in key state-owned forest areas such as the Northeast and Inner Mongolia. The main objective was to solve the recuperation and recovery and development of China's natural forests by imposing a ban on natural forests and significantly reduce the output of timber products, diverting and resettling forest area staff and workers and other measures. The first phase of the natural forest protection project was implemented from 2000 to 2010, with a total investment of 118.6 billion yuan. By 2012, 485,200 hectares of natural forest were protected by program.

In 2005, the Chinese government launched the "Overall Plan for Ecological Protection and Construction Projects in Sanjiangyuan Natural Reserve of Qinghai Province." The project was officially launched to ban animal husbandry, animal husbandry and fishery and to relocate grass and livestock. Administrative units of Sanjiangyuan region do not assess GDP,

and ecological protection and construction have been listed as the main examination contents for the work of governments at all levels in the region. By 2016, the first phase of the ecological protection and construction projects in Sanjiangyuan natural reserve of Qinghai Province has completed the inspection and the investment was 8.54 billion yuan.

2.5 Developing Gross Ecosystem Product accounting

For decades Chinese officials have been evaluated for promotion in terms of their performance related to GDP. This fueled China's unprecedented economic growth rates but provided no incentive for conservation of ecosystem services. Countries have adopted different indices to track macro level progress on human development (e.g., Human Development Index), but there is a lack of a comparable index for the ecosystems and environment. In order to align institutional behavior with ecosystem protection, the Chinese government is developing a balance sheet on ecosystem goods and services known as Gross Ecosystem Product (GEP) accounting to evaluate the effectiveness and progress of conservation efforts and policy. GEP is defined as the monetary value of final ecosystem goods and services benefitting people, where value of a good or service is its price times its bio-physical quantity. GEP, like GDP, is an accounting rather than an economic welfare measure (Fig 8).

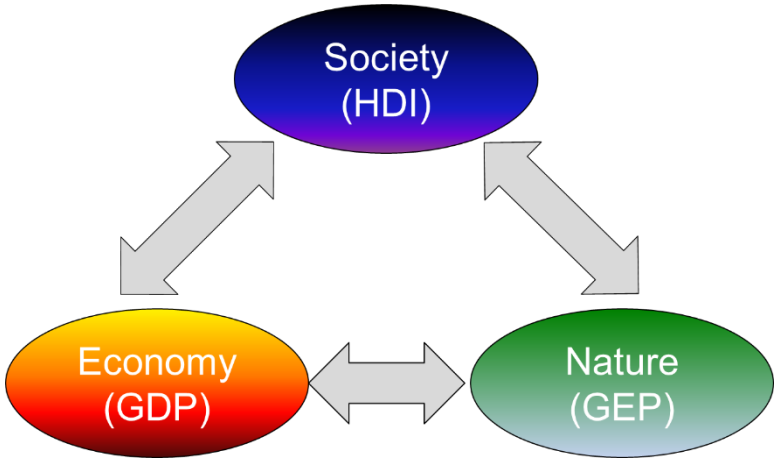

Fig 8. Countries have adopted different indices to track macro-level progress on human development (e.g. Human Development Index [HDI]) and economic development (e.g. Gross Domestic Product [GDP]), but we lack a comparable index for the environment. We propose China develops a national accounting system on the goods and services provided by ecosystems known as Gross Ecosystem Product (GEP).

GEP is the valuation of final ecosystem goods and services in monetary terms, estimated using equation (1) for an area or a country on an annual time-frame.

$$GEP = EPV + ERV + ECV \qquad (1)$$

where, GEP is the gross ecosystem products, EPV is the value of ecosystem provisioning services, ERV is the value of ecosystem regulating services, and ECV is the value of ecosystem cultural services. GEP national accounting would communicate the biophysical condition of the natural capital stocks as well as the monetary value of the flow of ecosystem goods and services to society.

Development of GEP has relied strongly on partnerships, such as with the International Union for Conservation of Nature (IUCN) to refine the definition of GEP to generate a pilot

methodology for linking GEP to GDP. Since 2014, GEP has been supported by the Chinese government and multilateral organizations such as the Asian Development Bank (Ouyang et al. 2017). The pilot sites include four provinces (Qinghai, Hainan, Inner-Mongolia, and Guizhou); ten cities (Shenzhen, Lishui, Fuzhou, Tonghua, Qiandongnan, Hinggan League, Ganzi, Haikou, Puer, and Erdos); and more than one hundred counties (for instance,Deqing, Arxan, Xishui, Shunde, Pingbian, and Eshan).

3. Existing natural capital accounting and literature in China

3.1 Ecosystem services accounting in China

Through literature research, a total of 1200 articles on "Ecosystem Services" and 988 articles regarding the "valuation of ecosystem services," with the term "value" included in their abstracts, were retrieved from the Core Database of China National Knowledge Infrastructure until now. Based on this literature, analysis was made to the contribution of studies on wetland, forest, grassland and farmland ecosystems, as well as valuation of “land” based ecosystem services. The highest contribution came from regional scale, such as marine, river basin, and some other regional ecosystems, registering 42.43%, followed by forest (24.7%) and wetland (19.12%). Studies on farmland, grassland, and land-based ecosystem services took up a small share. Ouyang et al. (1999) estimated the economic value of terrestrial ecosystem services in China, and the research findings, which were published in the Journal of Ecology, have been cited over 2000 times. Xie et al. (2003) developed, with the Tibetan Plateau ecosystem as an example, the Value Factor Equivalent Scale for Chinese Terrestrial Ecosystem Services, which has also been cited over 2000 times and has laid a foundation for the valuation of ecosystem services in China. There is also domestic research on the valuation of farmland, wetland, forest, and grassland ecosystem services in China. In general, the valuation of terrestrial ecosystem services is a hot topic in both ecology and geography.Ecosystem services are currently evaluated using two main approaches in China, namely a parametric approach, integrated modeling approach.

At the national scale, Ouyang et al. (1999) evaluated terrestrial ecosystem services in China by modeling method, including organic matter production, carbon sequestration and release, nutrient cycling and storage, soil conservation, water conservation, and environmental purification, and calculated an annual value of 30.488 trillion yuan. Meanwhile, Chen et al. (2000) estimated that the annual value of benefits provided by ten terrestrial ecosystems in China were was about 5.61 trillion yuan and that the annual value of benefits provided by two marine ecosystems was 2.17 trillion yuan. Using remote sensing technology, Pan (2004), Bi (2004), He (2005), and Zhu (2007) estimated that the annual value of ecological assets in terrestrial ecosystems in China was between 4 and 13 trillion yuan. In 2009, Professor Fu Bojie hosted the 973 Project, "China's Major Terrestrial Ecosystem Services and Ecological Security," which targeted the ecosystems that are most important to China's ecological security, including forest, wetland, grassland, and desert ecosystems. The study examined, at ecosystem, regional, and national levels, important ecosystem services, such as water source conservation and hydrological adjustment, water and soil conservation, wind and sand fixation, biodiversity conservation, and carbon sequestration. It is very important for us to comprehensively understand the spatial patterns and evolution characteristics of

ecosystem services in China, to develop theories and methodologies for studying ecosystem services, and to safeguard China's ecological security (Fu et al., 2012).

At regional scale, the “Value Factor Equivalent Scale for Chinese Terrestrial Ecosystem Services” that was initially proposed by Xie is used to valuate ecosystem services. For example, Zhao et al. (2013) examined, using the value-per-unit-area equivalence scale, the spatiotemporal evolution of ecological services in the Naoli River Basin during the past 60 years. By combining the scale with Costanza’s valuation approach, Jiang et al. (2010) explored the impact of land use change on the value of ecological services in the Shiyang River Basin and the change over the ten years. Based on the Poyang Lake Basin datasets of three years (1990, 2000, and 2008), Liu et al. (2017) valuated the ecosystem services of the basin and sub-basin and built the value structure using the Weaver combination index.

Forests ecosystem services accounting is another research hotspot. Zhao et al. (2004) classified forest ecosystem services into four categories (product provision, regulation, culture, and life support) and established a 13-indicator assessment system that included forest products and photosynthetic oxygen fixation. Based on the fifth national resource inventory dataset and the calculation methods of Costanza et al. (1997), Yu et al. (2005) used the parametric method to estimate that the economic value of carbon sequestration and oxygen release by forest ecosystems in China was equivalent to 1.439923 trillion yuan/yr, and Wang et al. (2009) estimated that the economic value of forest ecosystem services in China totaled 1176.339 billion yuan in 2003. More recently, domestic scholars have evaluated the services provided by forest ecosystems across China, according to or referring to this code. The studies consider the national scale (Wang et al., 2011; Niu et al., 2012) and small and medium-sized scale, including nature reserves (Liu, 2011; Wang, 2013), mountains (Liu et al., 2013; Liu, 2013), and county administrative areas (Dong et al., 2011; Xue, 2013), and cover the northeast, northern, central, southern, and northwestern regions of China.

Recently, China’s scientists are developing a new index based on ecosystem goods and service accounting known as Gross Ecosystem Product (GEP), a measure that translates ecological contributions to the economy into monetary terms. GEP is defined as the monetary value of final ecosystem goods and services benefiting to people. The Government of China is now actively working to develop and implement GEP. The National Development and Reform Commission (NDRC), in coordination with the Ministry of Ecology and Environment, has launched pilot studies of GEP at provincial, municipal, and county levels. These pilots are aimed at developing GEP for evaluating government performance in key regions (officially designated as “key ecological function zones”) and also for assessing the effectiveness of a policy to sustain cross-regional flows of ecosystem services, and improve livelihoods, through compensatory transfer payments between areas (62).

3.2 Gross Ecosystem Product Accounting

The work to develop GEP builds on two main strands of research. The first strand is the international effort to develop integrated environmental-economic accounts, including work led by the United Nations Statistics Division (UNSD) to develop the System of Environmental-Economic Accounting (SEEA) and the System of Environmental-Economic Accounting Experimental Ecosystem Accounting (SEEA EEA). SEEA EEA is currently under

revision with the objective to elevate it to an international statistical standard on par with the System of National Accounts (SNA).

The second strand of literature uses spatially explicit integrated ecological-economic modeling. This line of work builds from ecosystem modeling that predicts the flow of ecosystem services and then applies economic valuation methods to estimate the value of ecosystem services. Much of this work advances particular applications, ranging from analysis of specific policy interventions or scenarios at local to national levels. We build on this literature and combine it with a systematic accounting of the value of ecosystem goods and services so that it can be incorporating into a commonly reported framework consistent with the SEEA.

Our work on GEP contributes to the existing research in two main ways. First, GEP is a novel aggregate measure of the value of ecosystem services, which summarizes the contributions that nature makes to the economy. Second, we combine recent advances in ecosystem services modeling approaches with an integrated environmental-economic accounting framework consistent with the SEEA to demonstrate how to make progress on empirical measures with existing data.

The first step in constructing a measure of GEP is to assemble biophysical data defining metrics of ecosystem services (e.g., amount of grain production, water quality metrics, carbon sequestration). The second step is to find analogs for prices for ecosystem services. Some services are traded in markets (e.g. agricultural crops, timber, fish) and therefore market prices are readily accessible. For a few services, government policies have created markets such as for carbon that have in turn generated prices. However, many ecosystem services are provided entirely outside markets and therefore lack prices. In some of these cases, prices can be represented through a variety of non-market valuation techniques. In many other cases, simple cost-based measures can be used. For example, ecosystem services such as water purification can be priced by looking at the cost of removing nutrients via water treatments plants. Similarly, flood prevention services can be priced by evaluating the reduction in damages from reduced flooding. The value of a particular ecosystem service is simply its price in a particular location multiplied by the quantity of the service. GEP is then found by summing up the value over all ecosystem services. This approach provides a common unit comparator with GDP that uses tractable techniques, and readily available data.

4. Opportunities for using natural capital accounting to inform policy in China

As noted above, Chinese government is developing the new indicator known as Gross Ecosystem Product (GEP) accounting to evaluate the effectiveness and progress of conservation efforts and policy. GEP can provide decision-makers with clear and compelling evidence of the value of ecosystem services and the consequences of changing quality and amounts of ecological assets. A tractable measure of GEP can be widely applied for both planning and evaluation purposes including the evaluation of government policy and performance, land use and infrastructure planning, and can provide the basis for determining financial compensation for the provision of ecosystem services (Fig. 9).

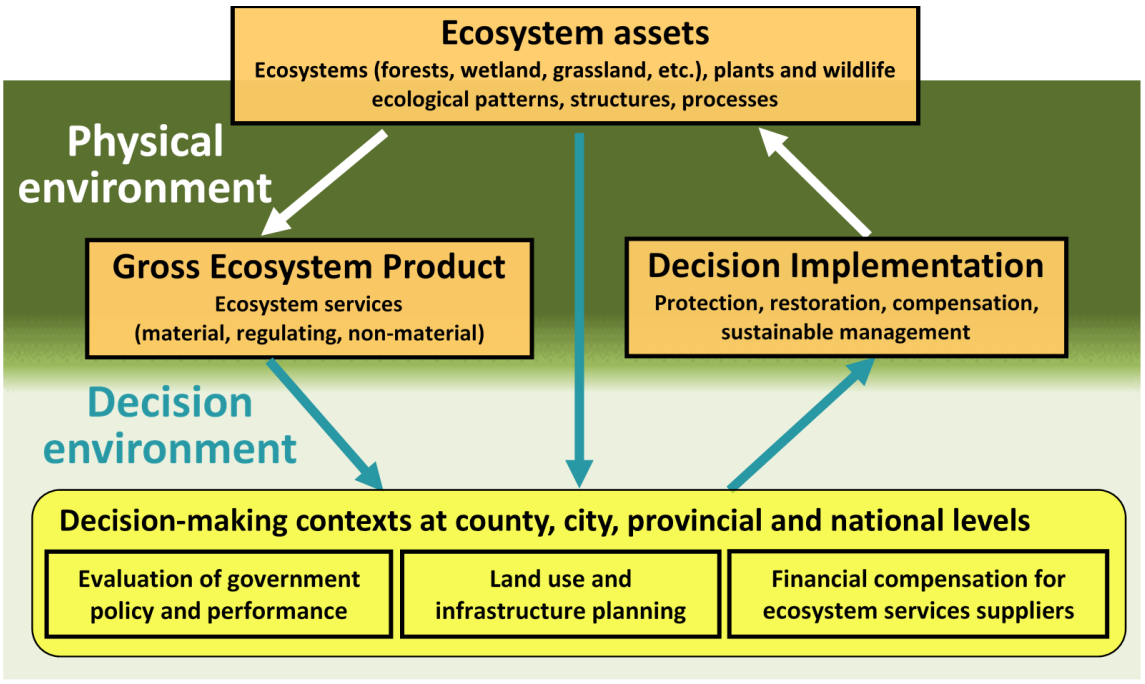

Fig 9. Relationships among ecosystem assets, GEP, and decision-making.

By measuring the value and geographic location of the production and use of intermediate and final ecosystem services, GEP can provide the basis for financial compensation across regions for provision of ecosystem services. At the same time, GEP offers the value of different ecosystem goods and services, is the foundation of market creating for eco-products trading. Such programs can also play an important role in conserving those ecological assets necessary for the provision of ecosystem services, can also play an important role in poverty alleviation as many regions.

4.1 Evaluating the effectiveness of eco-compensation policies and ecological restoration and engineering

The implementation of eco-compensation policies will both improve the eco-environment and properly rectify the regional imbalance in resources and economy, thereby promoting coordinated environmental and socioeconomic development, improving the living standards, and realizing sustainable development. There are plenty of eco-compensation polices at different scales in China. With the deepening of the work on eco-compensation, performance appraisal and eco-compensation policies must be integrated and performed consistently, in order to successfully appraise and supervise the advancement of eco-compensation by the government and to guide eco-compensation policies. When assessing performance, the implementation, result, role, and impact of eco-compensation policies are analyzed and measured systematically, and the policies' implementation efficiency, schedule compliance, acceptance, ecological effects, and indirect impacts on society and economy are determined. Measuring the implementation effects of eco-compensation policies is necessary and important for revising and improving eco-compensation policies and for maximizing the benefits of eco-compensation.

In 2014, the Chinese government requested assistance from the Asian Development Bank, in order to enhance the ability of the National Development and Reform Commission to evaluate the effectiveness of eco-compensation programs and the performance of local

administrations involved in them. Since TA started at June 2016, TA group has gone to Qinghai Province, Qiandongnan Prefecture of Guizhou Province, Pingbian County and Eshan County of Yunnan Province to conduct surveys and researches. The results of this interaction include the development of a methodology and approach for GEP accounting, establishment of a monitoring and evaluation system for target ecosystem services, and environmental improvement in the key ecological functional zones, all of which will enhance the National Development and Reform Commission's capacity to evaluate the impact of eco-compensation programs in China's key ecological functional zones and to assess the overall performance of local administrations. But are still many limitations and steps for wide-range application and implement.

4.2 Assessing the performance of governments in green development

Since the reform and opening up, China has gradually established a unique and relatively mature and effective system for assessing the performance and policy effects of local governments at all levels. Seen from design and variation directions of the indicator system of such systems in recent years, a general trend has emerged, featuring enhanced attention to environmental and ecological resources and a gradual increase in corresponding indicators. Meanwhile, individual regions are also exploring indicator systems that are more suitable to their respective socioeconomic status.

The assessment indicator systems of various regions have recently followed the five development concepts of "innovation, coordination, green, openness and sharing" and practically promoting the adjustment and improvement of the local government performance assessment indicator system. Since 2013, multiple provinces, including Guizhou, Fujian, Shanxi, Ningxia, Hebei, Zhejiang, and Shaanxi, have adjusted their assessment of cities, counties, and areas by reducing or eliminating GDP-based indicators. In 2014, Fujian Province eliminated its assessment of GDP for 34 counties and cities and implemented a performance evaluation method that prioritized agriculture and ecological protection. In July 2014, Shanxi Province issued an amended county economy assessment method, in which in eliminated "GDP" and "GDP growth rate" as indicators of state-level poverty-stricken counties. Both Ningxia Province and Hebei Province have also eliminated GDP-based indicators for assessing impoverished counties and have, instead, prioritized the improvement of living standards and reduction of poverty. Shaanxi Province lowered the weight of GDP-based indicators, now considers municipal GDP values that reach the provincial average as acceptable, no longer awards points for over-fulfilling GDP tasks, increased the weight of eco-environment protection indicators, and now awards points for over-fulfilling fog and haze treatment tasks. Since 2015, Zhejiang Province has lowered the weight of GDP-based indicators for 26 under-developed counties. In June 2015, at the meeting of the leading group for anti-poverty development, Guangxi Autonomous Region decided that it would eliminate GDP-based indicators from the assessment of eight counties and autonomous prefectures located in key ecological functional zones and that it would reduce the weight of GDP-based indicators in the assessment of its 25 poorest counties.

Systematically integrating GEP-based environmental and ecological indicators into the performance or policy effects assessment indicator systems of local governments at all levels will facilitate the directional adjustment and transformation of GDP-based indicator systems and corresponding assessment and evaluation systems, which will better guide the

key work of governments and facilitate the improvement of China's economic and social development.

4.3 Providing the basis for financial eco-compensation

The majority of the zones with high-quality ecological assets are located in rural and mountainous areas with high poverty rates where local people depend heavily on natural resources, and have limited employment opportunities. The restriction of industrialization and agriculture will significantly impact conventional modes of revenue generation thereby impacting incomes and living standards of local communities. Ecological compensation attempts to reduce conflicts between development and conservation by having beneficiaries (i.e. urban residents) pay suppliers (i.e. rural farmers) to protect ecosystems for specific services like maintaining clean drinking water. One of the most important steps is measuring the valuation of ecosystem services.

Known as the "water tower" of East and Southeast Asia, Qinghai is the source of three major rivers: The Yellow, The Yangtze and Mekong River. Qinghai provides a crucial store of natural capital and ecosystem service flows for much of China and Southeast Asian counties. The provinces that benefit from the ecosystem services generated in Qinghai tend to be far wealthier in conventional economic terms. Ouyang et al. (GEP) calculated the GEP of Qinghai Province based on the ecosystem services flow from upstream to downstream, and proposed some eco-compensation mechanisms, such as water funds in which downstream water users pay for protection of upstream watersheds (75, 77), it is possible to conserve ecosystem assets, and in the many cases like Qinghai, also help alleviate poverty and promote sustainable economic development. Many regions, such as Qinghai Province, are rich in ecosystem assets but relatively poor in conventional economic measures (per capita GDP). GEP accounting will provide theoretical basis and scientific directions for this item.

4.4 Offering foundation for value realization of eco-products

In a widely cited speech to the 19th Communist Party of China National Congress, President Xi Jinping said that "lucid waters and lush mountains are invaluable assets". Central government selected four pilots (Lishui City in Zhejiang Province, Fuzhou City in Jiangxi Province, Qinghai Province and Guizhou Province) for a new project "mechanism research for value realization of eco-products". Accounting the monetary value of ecological assets and ecosystem services is the first and most important step for value realization of eco-products, which is the foundation of market creating for this progress.

For many ecological products and ecosystem services, there are large gaps between where ecological modeling stops (e.g., the amount of nutrients in water supply) and where the valuation of ecosystem services begins (e.g., human health impacts). The effort here represents a start towards systematic accounting of GEP into financial market trade and value realization of ecological products, but much work remains.

5. Eco-compensation policies in China

In 2005, "accelerating the establishment of eco-compensation mechanism with the principle of 'having the developer protect, having the beneficiary compensate'" was first put forward in "Suggestion of the Central Committee of CPC on the 11th Five-Year Plan for National

Economy and Social Development “at the fifth Plenary Session of the 16th CPC Central Committee, and since then ecological compensation mechanism has already become one of the policy tools at the national level. Especially after the 18th CPC National Congress, the CPC Central Committee and the State Council attach great importance to the construction of compensation mechanism for ecological protection and proposed that “establish a system of paid use for natural resources and eco-compensation”. With the ecological civilization promotion in China since the 18th CPC National Congress, the practice progress of eco-compensation was also advanced rapidly.

2016, the General Office of the State Council released the Opinions of the General Office of the State Council on Improving the Compensation Mechanism for Ecological Protection, stating that "By 2020, eco-compensation coverage all key areas such as forests, grasslands, wetlands, deserts, oceans, rivers, key ecological functions and other important areas, the level of compensation and economic and social development to adapt to cross-regional and inter-basin compensation pilot demonstration made significant progress, diversified compensation mechanism was initially established, establishing eco-compensation system according with China's national conditions, promoting the formation of green production methods and lifestyles. "

At present, China's eco-compensation policies mainly include the sloping land conversion program, natural forest protection project, ecological forest compensation, ecological transfer payment, program of returning grazing land to grassland, policy of subsidy and reward funds for grassland ecological protection, wetland eco-compensation and other national level projects. At the provincial level, eco-compensation and ecological cooperation projects are mainly ecological compensation in the basin.

5.1 Natural forest protection program

China mainly implemented natural forest protection program in the upper reaches of the Yangtze River and the upper and middle reaches of the Yellow River, as well as natural forest protection program in key state-owned forest areas such as the Northeast and Inner Mongolia. The main objective was to solve the recuperation and recovery and development of China's natural forests by imposing a ban on natural forests and significantly reduce the output of timber products, diverting and resettling forest area staff and workers and other measures. The first phase of the natural forest protection project was implemented from 2000 to 2010 with the main compensation policies including forest management and maintenance fees, grants to the Ministry of Education, Health, Public Security and Justice Department of the state-owned forestry units, subsidies to the state-owned forestry units for fire protection, sanitation, subdistricts and other social public welfare undertakings shall be transferred to the provinces (autonomous regions and municipalities) administered by the local government for subsidies, with a total investment of 118.6 billion yuan. By 2012, 485,200 hectares of natural forest were protected by program.

5.2 Ecological forest compensation

In 2004, the state formally established the Central Government Ecological Forest Compensation Fund for the protection and management of key shelterbelts and special purpose forests. By 2012, a total of 1,867,500,000 mu of state-level public welfare forests as defined in the national division will all fulfill the compensation fund. In 2013, the

compensation rates for all state-owned non-commercial public welfare collectives and individuals raised from the initial annual subsidy of 75 yuan per hectare (5 yuan / mu / year) to 225 yuan per hectare (15 yuan/mu/year), compensation fund reached 14.93 billion yuan.

5.3 Program of returning grazing land to grassland

Since 2003, China has implemented the program of "returning grazing land to grassland" to the grassland ecological protection project, and has subsidized feed grazing for grazing ban and seasonal grazing throughout the year and subsidized the construction of grassland fences. In 2003-2010, the program of "returning grazing land to grassland" was carried out in Inner Mongolia, Xinjiang, Qinghai, Gansu, Sichuan, Tibet, Ningxia, Yunnan 8 provinces and Xinjiang Production and Construction Corps. The central government invested a total of 13.6 billion yuan in capital construction and arranged grasslands, with a task force of 778 million hectares of fencing construction, feed grain subsidies are given to pastoralists who implement fence fencing in the project area. The program benefited 174 counties, over 900,000 farmers and herdsmen, and more than 4.5 million farmers and herdsmen. In 2011, after the promulgation of the policy of subsidies for grassland eco-protection, the policy of "returning grazing land to grassland" has been adjusted. Grassland banning grazing and grazing is no longer implemented in any way as a fence construction. Supporting the construction of sheds and artificial grasslands, increasing the proportion of central government subsidies and standards, feed grain subsidy to grassland ecological protection grants incentives.

5.4 Policy of subsidy and reward funds for grassland ecological protection

The policy of subsidy and reward funds for grassland ecological protection that China implemented since 2011 is the most important grassland ecological compensation mechanism in China. Since 2011, the central government has allocated funds of 13.6 billion yuan each year in Inner Mongolia, Xinjiang, Tibet, Qinghai, Sichuan, Gansu, Ningxia and Yunnan 8 provinces and autonomous regions to establish a comprehensive grassland eco-protection subsidies reward system. Grazing ecological protection subsidies include 6 yuan per mu grazing subsidies per year, 1.5 yuan per mu per year grass savings balance awards and herdsman subsidies.

With the continuous implementation of a series of major grassland protection and construction projects, the total output of natural grassland in the country reached 102.2193 million tons in 2014, and the productivity of grassland continued to maintain a high level. The vegetation condition in grassland was obviously improved, and the grassland vegetation coverage of the whole country was 53.6%, the utilization of grasslands is more reasonable, the average overloading rate of livestock in the key natural grasslands in China dropped from 30% in 2010 to 15.2% in 2014.

5.5 Wetland eco-compensation

In 2009, China officially proposed the establishment of a wetland eco-compensation system and started the national wetland eco-compensation pilots project. From 2010 to 2011, the central government invested a total of 400 million yuan to carry out 111 wetland protection grants, and achieved remarkable results. In 2014, the central government allocated 1.594 billion yuan of forestry-related subsidies for wetland-related expenditures and started the

pilot projects of returning farmland to wetland, compensating for wetland ecological benefits and rewarding wetlands. During the 12th Five-Year Plan, the total investment in wetland protection planning is 129 billion yuan, of which the central government has 55 billion yuan, a total of 738 projects, over 590 protection projects, 110 comprehensive harnessing projects, 26 sustainable use demonstration projects, capacity building more than 10 projects, has now implemented 115 projects.

5.6 Basin eco-compensation

In the early 1990s, China began to explore ecological compensation in the basin. The "Law of the People's Republic of China on Prevention and Control of Water Pollution", passed the revision in 2008, is a landmark of ecological compensation in the watershed. It was the first time that the content of the compensation for water environment and ecological protection was put forward in the law formally promulgated by the state. In May 2008, the Ministry of Environmental Protection approved the first batch of pilot areas for ecological compensation such as the Min River Basin in Fujian Province. There are four kinds of basin eco-compensation methods: financial compensation, in-kind compensation, policy compensation and intellectual compensation. Current watershed ecological compensation cases include inter-basin horizontal ecological compensation mechanisms among different provinces and ecological compensation mechanisms covering a certain province or multiple prefectures in the province.

Since 2011, the Ministry of Finance and Ministry of Environmental Protection led the pilot implementation of the national pilot scheme of ecological compensation mechanism across the province in Xin'anjiang River Basin. Anhui Province on the upstream and Zhejiang Province on the downstream of the Xin'anjiang River Basin agreed that as long as the water quality of Anhui reaches the exit level, the downstream Zhejiang Province give an annual compensation of 1 million to Anhui. By the end of 2013, the central government invested a total of 850 million yuan in pilot projects of the Xin'anjiang River Basin. In Zhejiang and Anhui provinces, the compensation funds were appropriated to 420 million yuan and a total of 1.27 billion yuan. Since the implementation of the policy, both the symptoms and the symptoms of pollution control have initially appeared. Quality remained stable, the initial target of achieving water quality standards. There are also cases of ecological compensation in inter-provincial river basins. The Guangxi Province and the Guangdong Province signed the Agreement on Cooperation in Transboundary Water Environment Protection in the Kyushu River Basin. The two provinces (autonomous regions) governments each contributed 300 million yuan to establish Kyushu Inter-provincial water conservancy and environmental protection cooperation funds. As well as eco-compensation projects in the inter-provincial watersheds in Shaanxi and Gansu provinces in the Weihe River Basin.

The cases of ecological compensation covering the whole province or several prefectures and cities in the province mainly include the implementation of the compensation mechanism for water environment covering the province in 2014 in Jiangsu Province and the eco-compensation for key river basins in Fujian Province implemented in 2015 Case, as well as the main river basins in the scope of implementation, covering multiple cities and provinces at the provincial level eco-compensation cases such as eco-compensation for water pollution control in Chishui River Basin in Guizhou Province, eco-compensation in Xiangjiang River Basin, eco-compensation of water environment in the inter-administrative

boundary of Muling River and Hulan River Basin in Heilongjiang Province, and provincial water pollution compensation in Shayinghe River Basin in Henan Province.

6. Institutional settings for advancing natural capital accounting in China

6.1 Ecological civilization construction

The Central Committee of the CPC and the State Council issued the Comprehensive Program for Reform of the Ecological Progress System in 2015. It emphasized that ecological conservation is vital not only to sustained, healthy economic development, but also to political and social progress, and must therefore be given a position of prominence and incorporated into every aspect and the whole process of economic, political, cultural, and social development. This program especially highlighted the importance of natural capital protection as follow:

Foster an understanding that lucid waters and lush mountains are invaluable assets. Fresh air, clean water sources, beautiful rivers and mountains, fertile land, and biological diversity form an ecological environment that is essential to human survival. As development is a top priority for China, it is imperative to protect forests, grasslands, rivers, lakes, wetlands, seas, and other natural ecosystems.

Cultivate respect for the value of nature and natural capital. Natural ecosystems have value; the protection of nature is a process of increasing the value of nature and the value of natural capital, and means the protection and development of the productive forces. Protection efforts should, then, be adequately rewarded and come with economic returns.

6.2 Ecological compensation policies improvement

During the 18th National Congress of the Communist Party of China (CPC), the Chinese government noted that “Resource consumption, environmental damage, and ecological benefits shall be brought into economic and social evaluation systems to reflect the system goal, assessment methods, reward and punishment mechanisms of ecological civilization requirements;” “Price and tax reform of resource products shall be deepened; a resource paid to use the system and an eco-compensation system shall be established to reflect market supply and demand, the scarce degree of resources, the ecological value and inter-generational compensation;” “Eco-environmental protection accountability systems and environmental damage compensation systems shall be completed;” regional GDP assessment shall be cancelled in limited developmental areas, and key countries of poverty relief, and development of weak ecology.

Improving the ecological compensation system. Explorations will be made into establishing a diversified compensation mechanism, transfer payments to major ecological functional zones will be increased step by step, and the incentive mechanism that links ecological protection performance with fund allocation will be improved. Measures will be drawn up for implementing a mechanism, principally for local compensation, and supported by additional funds from the central budget, by which local governments compensate each other for ecological or environmental damage and ecological conservation efforts. Local governments are encouraged to launch ecological compensation trials. Efforts will continue in carrying out the ecological compensation pilot initiative for the Xin’an River ecosystem. Help will be given

to carry out trans-regional ecological compensation pilot initiatives in the Beijing-Tianjin-Hebei water source conservation area, in areas along the Jiuzhou River in Guangxi and Guangdong, and in areas along the Ting and Han rivers in Fujian and Guangdong. Explorations will be made into carrying out pilot ecological compensation initiatives in the Yangtze River basin- an environmentally sensitive region.

6.3 Government performance assessment

The “Decision of the CCCPC on Some Major Issues Concerning Comprehensively Deepening the Reform” (hereafter referred to as “Decision”) creatively suggested that we “explore ways to compile a natural resource balance sheet.” Exploring the creation of balance sheets for natural resource assets. Guidelines will be formulated on preparing balance sheets for natural resource assets. Asset and liability accounting methods will be developed for use with water, land, forest, and other types of resources; accounts will be established for accounting natural resources in physical terms; classificatory criteria and statistical standards will be clearly laid out; and changes in natural resource assets will be regularly assessed. The preparation of balance sheets for natural resource assets will take place on a trial basis at the municipal (county) level, with physical accounts of major natural resource assets being assessed and results released.

Auditing outgoing officials’ management of natural resource assets. On the basis of the preparation of balance sheets for natural resource assets and making reasonable allowance for objective natural factors, active efforts will be made to explore the objectives, content, methods, and appraisal indicators for auditing outgoing officials’ management of natural resource assets. Based on the changes in natural resource assets within their area of jurisdiction during their term of office, through auditing, an objective evaluation will be carried out of the outgoing official’ s management of natural resource assets; an official’ s liability will be determined in accordance with the law, and auditing results will be put to better use. Trials for preparing balance sheets for natural resource assets and for audits of the management of natural resource assets by outgoing officials will be conducted in the cities of Hulun Buir in Inner Mongolia, Huzhou in Zhejiang, Loudi in Hunan, Chishui in Guizhou, and Yan’ an in Shaanxi.

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