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# Assessment of Desert Ecological Assets and Countermeasures for Ecological Compensation

BAO Yingshuang[#], CHENG Leilei[#], LU Qi[*]

Institute of Desertification Studies, Chinese Academy of Forestry, Beijing 100091, China

**Abstract:** Can deserts be transformed into resources, into assets, and further into cash? It is necessary to scientifically assess desert ecological assets and incorporate them into the national economic accounting system and the current evaluation system for socio-economic development. This study will provide a scientific basis and robust data for establishing a target system that is compatible with both ecological civilization and an associated reward and punishment mechanism, as well as for designing and implementing effective compensation policies for desert ecosystems. This paper first defines desert ecological assets, and then develops a framework for assessing them based on the evaluation of desert ecological resources and desert ecosystem services. This framework paves the foundation for quantitatively assessing desert ecological assets and preparing balance sheets of desert ecological assets. Finally, this paper analyzes current policies relating to desert ecological compensation, discusses how to design compensation policies based on assessment of desert ecological assets, and puts forward suggestions for improving current policies.

**Key words:** ecological assets; ecological compensation; desertification combat; ecosystem services; desert ecosystem

## 1 Introduction

Ecological asset assessment and ecological compensation mechanisms have emerged as research frontiers and hotspots for further study (Gao et al., 2013; Ouyang et al., 2013; Li et al., 2009). In China, they are also important to the institution for developing an ecological civilization. The *General Plans for the Reform of the Ecological Civilization* made it clear that major goals are to cultivate respect for the value of natural resources and natural capital, improve the ecological compensation mechanisms, improve the assessment system of ecological conservation civilization performance, and incorporate ecological benefits into a comprehensive evaluation system for socio-economic development. The Report to the 18th National Congress of the Communist Party of China (CPC) explicitly stated that "Resource consumption, environmental damage and ecological benefits should be covered by the system for evaluating socio-economic development, and related goals, evaluation methods and reward and punishment mechanisms should be adopted in keeping with the need of promoting ecological civilization". The Report to the 19th CPC National Congress put forward that we will set up diversified market-based mechanisms for ecological compensation. Under the circumstances, there is an urgent need for in-depth research into theories and methods for ecological asset assessment and ecological compensation, so as to provide a scientific basis for building an ecological civilization system.

Desert ecological assets are an important component of

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**First author**: BAO Yingshuang, E-mail: bysh0623@sina.com; CHENG Leilei, E-mail: chengleilei@caf.ac.cn. # BAO Yingshuang and CHENG Leilei contribute equally to the work.
***Corresponding author:** LU Qi, E-mail: Luqi@caf.ac.cn

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China's ecological assets. Deserts are mainly distributed in the northwestern arid and semi-arid regions and are among the most ecologically vulnerable areas in China. Desert ecosystem, as the typical ecosystem in northwestern China, spans approximately $1.65\times10^6$ km$^2$ (Lu et al., 2016), covering eight of the greatest deserts, four of the largest sandy lands, and the vast Gobi desert. With unique structures and functions, the desert ecosystem is materially essential for the survival and development of residents in desertified areas, and more importantly it provides important guarantees for social stability, economic growth, and regional and even global ecological security. Therefore, desert ecological assets should be assessed in a scientific and systemic manner and incorporated into the national economic accounting system and the current evaluation system for socio-economic development. Meanwhile, appropriate standards should be formulated for desert ecological compensation. These standards will offer a scientific basis and data support for designing and improving ecological compensation policies designed to combat desertification, and establish related goals, evaluation methods, and reward and punishment mechanisms in accordance with the needs of promoting ecological civilization. These developments will also advance and enrich theories, methods and techniques of ecological asset assessment and ecological compensation.

## 2 Definition of desert ecological assets

### 2.1 Ecological assets

The concept of ecological assets originated from the philosophy of sustainable development. The Brundtland Report entitled *Our Common Future* (1987) mentioned ecological capital when expounding the idea of sustainable development. Domestic scholars separately defined ecological assets from their own perspectives. Wang & Wang (2001) defined ecological assets as ecological resources that are owned by the state and can generate direct, indirect or potential benefits which can be measured in monetary terms. This definition emphasizes the potential economic profitability and the ownership of ecological assets.

Chen & Huang (2003) considered ecological assets as ecological landscape entities whose owners can obtain economic benefits resulting from ownership. This view emphasizes the rights to own and use ecological assets and the integrity and potential economic profitability of the ecological landscape. Gao & Fan (2007) argued that ecological assets should encompass all natural resources and environments that can provide services and benefits to humans. These services and benefits include the tangible supply of physical resources, such as minerals, fruits, woods, and water resources, and ecological services in intangible and non-physical forms, such as air purification, oxygen supply, climate regulation, and landscape recreation. Gao et al. (2013) further explained ecological assets as organismal and derivative entities that have material and environmental production capacities and provide services and benefits to humans, including fossil energy and ecosystems.

Yan et al. (2009) made a distinction among ecological assets, ecological resources, and ecological capital, and described the process by which ecological resources are transformed into ecological assets and further into ecological capital. In their opinion, ecological resources mean the natural resources that can provide humans with ecological services or ecological carrying capacities; ecological assets mean clearly owned scarce natural resources that can bring benefits to their owners under certain technological and economic conditions; and ecological capital means the stock of ecological assets that can generate future income flows. Ecological resources can be transformed into ecological assets with clearly defined property rights, and then ecological assets are input as factors of socio-economic production to become specific ecological capital. The value of ecological capital is reflected in ecological products and services. The assetization of ecological resources represents the process of change in the sequent forms of ecological resources, ecological assets, ecological capital, and finally ecological products. Ecological capital is the ultimate form of ecological resources, and ecological capitalization is an important way of achieving the value of ecological resources.

Foreign scholars prefer to use the term "natural capital" instead of ecological assets. Capital refers to the stock that yields flows of useful products and services into the future (Hicks, 1974). The concept of natural capital was formally advanced by two British environmental economists Pearce & Turner (1990) in their book *Economics of Natural Resources and the Environment*. They introduced natural capital corresponding to cultivated capital in the production function in economics. Daly (1996) clearly defined natural capital as the stock of natural resources and environmental assets that can provide flows of useful products or services at present or in the future.

### 2.2 Deserts as ecological assets

Based on the existing definitions, desert ecological assets are defined as the stock of desert ecological resources and desert ecosystem services that can yield flows of products/services at present or in the future. They can be divided into two broad categories, i.e. desert ecological resource assets and desert ecological service assets. Desert ecological resource assets include desert land and biological resources which can be used for agricultural, pastoral, forestry, and medicinal purposes. Desert ecological resource assets directly provide flows of products that can largely be traded in markets. In contrast, desert ecosystem service assets mainly provide flows of services that cannot be physically traded in markets, including regulatory services, cultural services and supporting services.

Taking into account China's actual conditions, desert

ecosystem services are grouped into six categories, i.e. wind break and sand fixation, soil conservation, water resources regulation, carbon sequestration, biodiversity conservation, and landscape recreation (Lu et al., 2016). Wind break and sand fixation are the most important ecological functions provided by desert ecosystems. Desert vegetation slows down the flows of wind and sand and thereby any damages to production and life due to flowing sand driven by wind are reduced. Farmland shelterbelts in desertified areas are conducive to increasing crop output; and pasture shelterbelts can facilitate grass growth, shelter livestock, and increase livestock productivity. Compared with other ecosystems, wind break and sand fixation are unique services provided by desert ecosystems.

Soil conservation is one of the basic ecological functions of terrestrial ecosystems. The soil conservation of desert ecosystems consists of two aspects, i.e. forming new soil conducive to organism survival and development after sand and dust transport, and conserving soil nutrients through fixing soil by desert vegetation. Water resources are important for keeping the regular operation and ecological balance of desert ecosystems, and serve as major carriers of energy flow and material circulation within desert ecosystems. The regulation of water resources by desert ecosystems affect hydrological processes such as water distribution, consumption and balance through vegetation and soil, and mainly consist of freshwater supply, water conservation, and climate regulation.

Carbon sequestration is an important air regulation function performed by desert ecosystems, and it plays an irreplaceable role in maintaining the dynamic equilibrium of carbon dioxide in the atmosphere, mitigating the greenhouse effect, and providing basic conditions for human survival. It consists of carbon sequestration by vegetation and by soil. Biodiversity conservation is one of the core functions of desert ecosystems. China's desert ecosystem involves complex natural environments spread over a wide area. It embraces rich, varied and distinctive animal and plant species, and provides habitats which allow many rare animals, plants, and microbial species to survive and reproduce. In addition, China's desert ecosystem has not only unique recreational natural resources, such as *populus euphratica*, Mingsha Mountain, Moon Lake, Urho Ghost City and mirage, but also time-honored recreational cultural resources, such as Dunhuang Mogao Grottoes and Loulan Sites. These recreational resources are valuable for tourism, leisure, scientific and archeological investigations, adventures, and many other purposes.

## 3 Framework and methods for assessing desert ecological assets

### 3.1 Assessment framework

The desert ecological asset assessment framework for qualitatively describing and measuring desert ecological assets provides the foundation for quantitative assessment of ecological assets. The United Nations Statistical Commission and its collaborators published the *System of Environmental-Economic Accounting 2012: Experimental Ecosystem Accounting* (SEEA-EEA) in 2014. The SEEA-EEA defines ecosystem assets and proposes to measure ecosystem assets from two aspects, i.e. ecosystem status & scope and ecosystem services. China has formulated several national forestry standards relating to ecological asset assessment, such as the *Assessment Criteria of Desert Ecosystem Services in China* (2012), the *Technical Specifications for Assessment of Forest Resource Assets*, and the *Technical Specifications for Assessment of Natural Resource (Forest) Assets*.

With reference to the SEEA-EEA and relevant domestic standards, and taking into account the characteristics and major problems of deserts and various ecological conditions across regions in China, an assessment framework is developed for desert ecological assets, and associated indicators for calculating the value of desert ecological assets are selected, see Fig. 1.

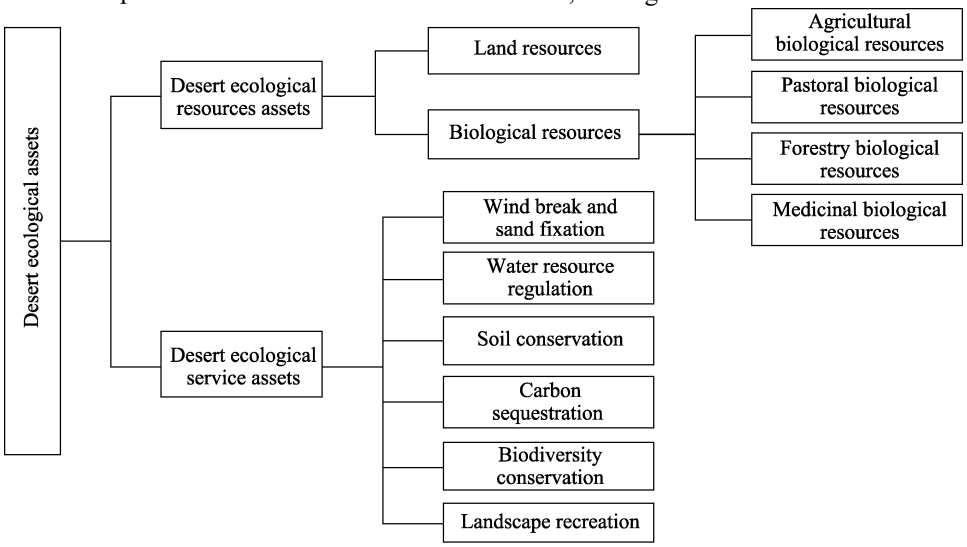


Fig. 1 Assessment framework for desert ecological assets

### 3.2 Assessment methods

3.2.1 Desert ecological resource assets

(1) Land resource assets

Land resources in desertified areas can be classified into subgroups according to land use types specified by China's national standard the *Current Land Use Classification*. The value of land resources can be estimated by multiplying the area of each type of land and associated rents.

$$VEA_{dl} = \sum_{j=1}^{N} \frac{1}{(1+\delta)^{j-1}} \times \left( \sum_{k=1}^{K} LA_{k,j} \times LR_{k,j} \right) \quad (1)$$

where $VEA_{dl}$ is the value of land resource assets, $LA_{k,j}$ is the area of the *k*-th type of land in year *j*, and $LR_{k,j}$ is the rent of the *k*th type of land in year *j*. *k* denotes a specific land use type, and *K* is the total types of land use. *j* is a specific year, and *N* is the calculation period. $\delta$ is the discount rate.

(2) Biological resource assets

Biological resources in desertified areas can be broadly divided into four categories according to their uses, i.e. agricultural biological resources, pastoral biological resources, forestry biological resources and medicinal biological resources. The value of ecological resource assets can be estimated based on the area, productivity, and product price of each type of biological resource.

$$VEA_{br} = \sum_{j=1}^{N} \frac{1}{(1+\delta)^{j-1}} \times \left( \sum_{i=1}^{4} LAR_{i,j} \times LPR_{i,j} \times RP_{i,j} \right) \quad (2)$$

where $VEA_{br}$ is the value of biological resource assets, $LAR_{i,j}$ is the area of the *i*-th type of biological resources in year *j*, $LPR_{i,j}$ is the productivity per unit area of the *i*th type of biological resources in year *j*, and $RP_{i,j}$ is the price of product of the *i*-th type of biological resources in year *j*. *i* denotes the biological resource type. *j* is the specific year, and *N* is the calculation period. $\delta$ is the discount rate.

(3) Desert ecological resource assets

The total value of desert ecological resource assets is the sum of the value of land assets and the value of biological resource assets.

$$VEA_{dr} = VEA_{dl} + VEA_{br} \quad (3)$$

where $VEA_{dr}$ is the total value of desert ecological resource assets.

3.2.2 Desert ecological service assets

The assets of desert ecosystem services can be regarded as the total value of desert ecosystem service flows. Therefore, it is necessary to carry out accounting for desert ecosystem service assets based on the assessment of desert ecosystem services. With reference to the *Assessment Criteria of Desert Ecosystem Services in China* (2012) and Cheng et al. (2016), the physical quantity and monetary value of desert ecosystem services are measured, covering wind break and sand fixation, water resource regulation, soil conservation, carbon sequestration, biodiversity conservation, and landscape recreation. On this basis, desert ecological service assets are valuated using the following formula:

$$VEA_{de} = \sum_{j=1}^{N} \frac{1}{(1+\delta)^{j-1}} \times (V_{j,\mathrm{WSF}} + V_{j,\mathrm{WRR}} + V_{j,\mathrm{SC}} + V_{j,\mathrm{CS}} + V_{j,\mathrm{BC}} + V_{j,\mathrm{LR}}) \quad (4)$$

where $VEA_{de}$ represents the value of desert ecological service assets, and $V_{\mathrm{WSF}}$, $V_{\mathrm{WRR}}$, $V_{\mathrm{SC}}$, $V_{\mathrm{CS}}$, $V_{\mathrm{BC}}$, and $V_{\mathrm{LR}}$ indicate the value of these desert ecosystem services in year *j* respectively, including wind break and sand fixation, water resource regulation, soil conservation, carbon sequestration, biodiversity conservation, and landscape recreation. *j* denotes the specific year and *N* is the calculation period. $\delta$ is the discount rate.

3.2.3 Desert ecological assets

The total value of desert ecological assets is the sum of the values of desert ecological resource assets and desert ecological service assets.

$$VEA = VEA_{dr} + VEA_{de} \quad (5)$$

where *VEA* is the total value of desert ecological assets.

## 4 Desert ecological compensation policy

### 4.1 Assessment of desert ecological assets and desert ecological compensation

(1) Assessment of desert ecological assets lays a theoretical and scientific foundation for determining the standards of desert ecological compensation.

The assessment of desert ecological assets rests on the physical quantification of desert ecological assets, including desert ecological resources and desert ecological services. The value of desert ecological assets depends on the determination of their prices, in particular the value of ecological services, which determines ecological compensation standards. Based on the theory of externalities in economics, the basis and assessment methods for ecological compensation standards can be unified through the internalization of positive and negative externalities. In terms of positive externalities, ecological compensation standards should either take into account the direct input for ecological protection and the associated opportunity cost, or consider the value of ecosystem services instead. In terms of negative externalities, ecological compensation standards should focus on the reduction in social welfare due to the depletion of regional ecological services (such as water conservation, soil conservation, landscape beautification, climate regulation),

which result from vegetation destruction, soil erosion, water resource destruction, and biodiversity loss within a certain range caused by human activities, especially inappropriate exploitation activities for desert resources (Li, 2013). Therefore, the assessment of desert ecological assets is necessary for the determination of desert ecological compensation standards.

(2) The implementation of desert ecological compensation will further propel the standardization of techniques and methods for assessing desert ecological assets.

Several desert ecological compensation policies are being piloted, such as the subsidy for the enclosed and forbidden reserves of desertified land in western China and the subsidy and reward mechanism for grassland ecological protection in relevant provincial regions. The Chinese government is expediting the formulation of the *Ecological Compensation Ordinance* which will further clarify the basic principles, main fields, compensation scope, targeted groups, financing sources, compensation standards, stakeholder rights and responsibilities, evaluation methods, and accountability for ecological compensation. At the local level, regulatory documents and policies for ecological compensation have been also issued. All these efforts not only contribute to the standardization of techniques and methods for ecological asset assessment, but also promote the institutionalization and legalization of ecological compensation.

### 4.2 Current desert ecological compensation policy

At present, China is either implementing or piloting the following ecological compensation policies related to desert ecosystems.

(1) Forest ecological compensation

The compensation mechanism for forest ecological benefits was officially established in 2004 and is supported by central and local government funds. The compensation fund financed by the central government adopts different compensation standards based on the ownership of non-commercial forests: RMB 75 per hectare annually for stated- owned forests and RMB 150 per hectare annually for collectively-owned or individually-owned forests (State Forestry Administration and Ministry of Finance, 2009).

(2) Subsidy and grant for grassland ecological conservation

The subsidy and grant mechanism for grassland ecological conservation has been implemented in eight provincial regions since 2011, and extended to another five provinces in 2012. The mechanism currently covers all the pastoral and semi-pastoral areas in China, involving 11 provincial regions affected by desertification.

(3) Subsidy for the enclosed and forbidden reserves of desertified land

Since 2013, the Chinese government has been supporting the pilot program of subsidy for the enclosed and forbidden reserves of desertified land in seven provincial regions, including Inner Mongolia, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang. The central government allocated a subsidy of RMB 300 million to establish and maintain protection facilities for the enclosed and forbidden reserves of desertified land, purchase patrol equipment, and fix the shifting sand dunes in the periphery of deserts.

In September 2015, the CPC Central Committee and the State Council made clear its intention to improve the ecological compensation system in the *Integrated Reform Plan for Promoting Ecological Civilization*. In May 2016, the State Council issued the *Opinions on Improving the Ecological Compensation Mechanism*, which proposed "by 2020, to achieve the full coverage of ecological compensation in key ecosystems (such as forests, grasslands, wetlands, deserts, oceans, rivers and farmlands), and exploitation prohibited areas and key Ecological Function Areas", and stressed the need "to pilot the enclosed and forbidden reserves of desertifed land taking ecological compensation as an important part, to strengthen ecosystem protection in sandy lands, and to improve the management and protection mechanism dominated by government procurement services."

### 4.3 Recommendations for improving desert ecological compensation

(1) Explore and pilot diversified compensation forms

The current scope of ecological compensation in China, mainly focusing on forests, grasslands, and mineral resources, is narrow. The ecological compensation mechanism for river basins, deserts, and wetlands is still in its infancy. The current standards of ecological compensation are low and they are not adjusted according to the specific conditions of different ecological regions. Besides, financing sources and compensation forms are simple. Transfer payments from the central government contribute a dominant share of the ecological compensation funds, while other funding sources, such as input from local governments, enterprises, preferential loans, and social donations, are conspicuously absent.

With the increase of transfer payments, the relationship among ecological construction, desertification control, and ecological compensation funds needs to be further clarified. Economic and legal instruments should be fully used to diversify ecological compensation forms. The support policies should be improved to guide and encourage lateral ecological compensation in desertified areas in the forms of financial subsidies, industrial transfer, and joint construction. Market-based compensation, such as carbon trading and eco-labelling for products and services, should be explored in order to expand funding channels. The piloting of the subsidy for the enclosed and forbidden reserves of desertified land and other desert ecological compensation should be strengthened in Northwestern China.

(2) Further clarify the rights and responsibilities of beneficiaries and protectors, and establish a bidirectional mechanism for compensation and punishment

Ecological compensation should be paid by beneficiaries

from ecological conservation or governments on behalf of the beneficiaries. The central government is mainly responsible for ecological compensation for national key Ecological Functional Areas, important ecological areas, and transprovincial river basins, while local governments are responsible for ecological compensation for key Ecological Functional Areas and important ecological areas within their respective jurisdictions. The ecological compensation mechanism for desertified areas should clearly define the responsible bodies (i.e. beneficiaries) and the targeted groups (i.e. compensation recipients) because it is difficult to generally obey the "beneficiary pays principle", whereby beneficiaries pay compensation to the producers of ecological benefits (Pan et al., 2008). The responsible subjects (central and local governments) and objects (recipients) of ecological compensation should be clearly emphasized, and desert ecological compensation should be integrated into the government budgets to ensure fulfillment of payment obligations based on detailed standards, so as to achieve an effective long-term mechanism for desert ecological compensation.

Meanwhile, local governments should supervise and punish, as appropriate, behaviors undermining desert ecology ecosystem and poor protection performance. At present, under the drive of economic interests, phenomena and behaviors that destroy the environment in pursuit of economic interests, such as over-cultivation, over-grazing and over-deforestation, can still be found in many areas that have already implemented ecological protection projects. The main reasons for these behaviors are that the benefits of destroying the ecosystem are much greater than the associated costs, and the existing punishment is not strict enough to effectively prohibit or discourage these behaviors (Luo et al., 2014). Therefore, a robust supervision mechanism and a bidirectional mechanism for ecological compensation and punishment are needed to control illegal activities such as destroying vegetation, wild animals and plant resources in desertified areas, or illegally occupying desertified land.

(3) Improve the supporting systems for desert ecological compensation

Among the current supporting systems for ecological compensation, the property rights system has not been well established. Clearly defined property rights are the prerequisite for clarifying the subjects and objects of ecological compensation and valuating ecological services. Ambiguity in property rights hinders the establishment of an ecological compensation mechanism. The ecological compensation standard system and the ecological service assessment system lag behind. For desert ecosystems, in particular, there is no common and authoritative indicator system or assessment method before consensus is reached on ecological service valuation and ecological compensation standard. In key ecological fields, the existing monitoring and evaluation resources are dispersed among various sectors and fail to support the implementation of desert ecological compensation. Therefore, it is imperative to improve the supporting systems for desert ecological compensation.

Specifically, the property right system should be reformed at a deeper level to clearly define forest rights, grassland contractual management rights, and water rights in desertified areas, while the registration system for property rights also needs further improvement. The ecological compensation standard system should be built as soon as possible, as a system in which ecological compensation standards are formulated based on the characteristics of different areas by applying refined assessment methods, and gradually raised to scale up compensation. Monitoring capacity building should be strengthened to establish a sound monitoring and evaluation indicator system and provide timely dynamic monitoring and evaluation information on desert ecosystems. A statistical information disclosure system for ecological compensation should be gradually formed, a performance assessment mechanism should be quickly introduced, and ecological service assessment agencies should be built.

(4) Consolidate the legal basis for desert ecological compensation

At present, there is no specific law dedicated to ecological compensation in China. The existing legal provisions concerning ecological compensation are scattered among various laws, leading to a lack of systematic and practical cohesiveness. With respect to desert ecological compensation, the *Law on Prevention and Control of Desertification* stipulates that "The people's governments at various levels located in desertified regions may get local rural collective economic organizations and their members organized, on a voluntary basis, to concentrate their efforts on rehabilitating the desertified land. The funds and labor put in by the said organizations and their members may be converted into the shares or capital funds for the rehabilitation projects or be compensated by other means," and "Where, for the special need of ecological protection, rehabilitated land is designated, upon approval, as natural reserves or enclosed and forbidden reserves of desertified land, the approving authority shall give reasonable financial compensation to the units or individuals that have rehabilitated the land." However, the specific rules for these legal provisions have not been formulated, and to some extent, they have lost any legislative significance. Therefore, in order to improve the desert ecological compensation mechanism, the legal basis should be strengthened so that laws are put in place, observed and strictly enforced. At the same time, the specific compensation standards for stakeholders should be clearly defined by the laws.

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# 荒漠生态资产核算与生态补偿对策

包英爽，程磊磊，卢　琦

中国林业科学研究院荒漠化研究所，北京 100091

**摘　要：**把荒漠变资源，把资源变资产，把资产变现钱？科学系统评估荒漠生态资产，把荒漠生态资产核算与国民经济核算体系对接、纳入现行经济社会发展评价体系，为建立体现生态文明要求的目标体系与奖惩机制提供科学依据和数据支撑，并最终制定政策实现对荒漠生态系统的有效、合理的补偿。首先，本文将界定荒漠生态资产概念，阐述荒漠生态资产的内涵；其次，基于荒漠生态系统服务评估，构建一套荒漠生态资产评估体系，为定量评估荒漠生态资产与编制荒漠生态资产负债表奠定基础；最后，本文将梳理现行的荒漠生态补偿政策，探讨如何基于荒漠生态资产评估来设计荒漠生态补偿政策，提供完善荒漠生态补偿政策的对策建议。

**关键词：**生态资产；生态补偿；荒漠化防治；生态系统服务；荒漠生态系统