Ecosystem Services in Agricultural and Urban Landscapes

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Part C

Measuring and Monitoring Ecosystem Services at Multiple Levels

7

Scale-dependent Ecosystem Service

Yangjian Zhang,[1] Claus Holzapfel[2] and Xiaoyong Yuan[1]

[1] Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, China
[2] Department of Biological Sciences, Rutgers University, Newark, USA

Abstract

The scale-dependent feature of ecosystem services is embodied in the scale dependency of ecosystem provider, ecosystem beneficiary, ecosystem service measurement and ecosystem service management. This study discusses each scale-dependent feature of ecosystem services, and two typical case studies are presented to illustrate the scale dependency of ecosystem service. One case deals with a park in one of the world's largest and most developed metropolitan area (New York), which represents local and regional ecosystem services of green space in an urbanized area. The other case covers the Tibet plateau, which represents a nature-dominated ecosystem that provides ecosystem services with both regional and global significance. Such hierarchically structured ecosystem services underline the importance of understanding ecosystem service in an integrated and comprehensive perspective.

Introduction

Ecosystem services, the basis for the existence and development of human society, refer to the benefits human derive, directly or indirectly, from ecosystem processes and functions (Costanza et al., 1997). An ecosystem service value is determined by ecosystem structure and processes at certain temporal and spatial scales. This chapter addresses the scale-dependent features of ecosystem service by first discussing the concepts of spatial and temporal scales, then how the scale

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determines ecosystem service. Ecosystem service provider, beneficiaries and management are all scale dependent and ecosystem services realized in various scales belong to each corresponding category. The various ecosystem services across scales are illustrated with two case studies ranging from a landscape to regional biome scale.

Scale

Scale refers to the spatial or temporal dimension of an object or process (e.g. size of area or length of time), characterized by both grain and extent (Peterson and Parker, 1998). The grain is the finest level of spatial resolution possible with a given data set (e.g. pixel size for raster data). The extent is the size of the study area or the duration of time under consideration.

The emergence of scale issue in ecological research and its fundamental significance to ecologists originates from the complex hierarchical organization feature of natural processes. Scale is intrinsic to all natural processes and rules (Farina, 1998). It can be classified as measuring scale and intrinsic scale. Measuring scale is the scale humans depend on to perceive the world and gauge the natural process and structure. It belongs to research techniques and develops with technique advancement. The intrinsic scale is the object under study and the ultimate goal of exploring across scales is to reveal the phenomena and rule based on certain scales (Fu et al., 2008). Measuring and intrinsic scales can be expressed as temporal or spatial scales. In describing natural process function, organizational scale is also used. It refers to the ecological hierarchy such as individual, population, community, ecosystem, landscape and biome.

Ecosystem service is scale dependent

Ecosystem services are not provided homogenously across a spatial landscape and they evolve through time. Some services are generated in one location at one time, but the benefit may be realized in a location different from the generation site or/and at another time. For example, the ecosystem service of regulated and extended water provision develops through time by water regulation provided by mountain-top forest that is often remote from the point of service.

The spatial and temporal features of ecosystem service refer to the different services provided by an ecosystem at various temporal and regional scales. In terms of temporal dimension, ecosystem service can be divided into long-term service (decades), seasonal service (year) and short-term service (hours). In terms of spatial dimension, ecosystem service can be considered as global service or regional service. Ecosystem service can be realized at a range of spatial scales, which can be a small wetland or a large forest ecosystem. At a global scale ($>10^6$ km^2), ecosystems provide services in regard to CO_2, N and P cycling and sequestration, and climate regulation (Hufschmidt, 1983). At a biosphere scale (10^4–10^6 km^2), ecosystems provides services of curbing floods, protecting ground water, controlling soil erosion and species habitat. At a landscape scale (1–10^4 km^2), ecosystem service can be reflected in decomposing pollutants and providing biodiversity, etc. An ecosystem composed of various species groups (<1 km^2) can serve to decrease noise and dust. In general, ecosystem services at various scales interact in ways that include mutual promotions and mutual constraints. Large-scale and long-term ecosystem services tend to constrain small-scale, periodic ones, while the groups of the latter ones converge to the former one (Clark et al., 1979; Holling, 1992).

The ecosystem service provider is scale dependent. A segment of a population or populations that provide ecosystem service in a given area is conceptualized as a service-providing unit (Luck et al., 2003). The scale of the service-providing unit determines the services output. For example, maintaining pest, weed and disease resistance of crops is provided at the genetic level (Luck et al., 2003); the biological control of crop pests is provided at the population and food-web level (Wilby and Thomas, 2002); water flow regulation service by vegetation is provided at the habitat and community level (Guo et al., 2000).

The ecosystem beneficiary is scale dependent

Since ecosystem service is provided in a scale-dependent pattern (Millennium Ecosystem Assessment, 2005), the corresponding beneficiaries exist across a range of scales as well. The beneficiary of ecosystem service can be classified into a hierarchy of socioeconomic institutions (Becker and Ostrom, 1995; O'Riordan et al., 1998), which ranges from the lowest institutional level, such as individuals and households, to higher level such as communities or municipalities, then to states or provinces, to nation, and the world. Stakeholders at each scale pay attention to the ecosystem service in which they have an interest and their utilization of ecosystem service likewise may vary greatly. For example, local residents value the timber woods of a forest, while state government pays more attention to its value for recreation or culture, and international communities see its value in offsetting global warming. Since ecosystem service and the service beneficiary both exist at a range of scales, participants are likely to step across their corresponding scale boundaries and conflict of interest results. From the standpoint of ecosystem service management, it is necessary to identify the complex ecosystem service structure.

Ecosystem service at certain spatial and temporal scales points to specific beneficiaries. The value of ecosystem service is highly related to the action of the beneficiary. It is perceivable that a service cannot be utilized if, for example, an ecosystem is providing a product for a short period only (e.g. wild berries) and immediate harvesting of this product is not possible.

Ecosystem service measurement is scale dependent

Ecosystem services are often ignored by policy makers since most of them have no direct commercial market values. Calculating ecosystem service in economic metrics might assist in improving the awareness of the public and the policy makers. However, ecosystem service measurement is highly likely to be biased due to a number of constraints.

The value of ecosystem service providers is highly likely to be over estimated since the same provider serves in different, often opposing, ways. To avoid such duplicate calculation, it is necessary to frame the ecosystem service into corresponding spatial and temporal scales. For example, a patch of forest interests local people for its timber value. At a global scale, it serves in reducing CO_2 levels. In this case, timber production service can not be counted at the larger, global scale.

Ecosystem boundary delineation can affect ecosystem service assessment fundamentally. Simply defining ecosystem boundaries based on easily identified physical boundaries, such as a lake or a stream, often is inadequate to address the complexity of natural systems within the question being addressed. However, some ecosystem processes or features coincide with the physical boundaries of certain area. For example, productivity calculation of a lake ecosystem can be simply conducted within the delineated lake boundaries, while the nutrient cycling of the lake ecosystem involves many processes crossing the lake boundaries, such as water flow and precipitation. It is challenging to define ecosystem boundaries since highly mobile organisms and constituents interact at multiple spatial and temporal scales. The scale-dependent features of ecosystem processes determine that the conceptualization of an ecosystem and the scope and validity of questions being asked within that ecosystem entail an appropriate choice of boundaries of an ecosystem (O'Neill et al., 1986).

Ecosystem service value assessment is constrained by limited understanding of ecosystem structures and processes across scales (Naeem, 2009). Ecosystem service identification is the basis for evaluating ecosystem service. The features of ecosystem service varying over temporal and spatial scales should be emphasized. In light of the dependence of ecosystem service on ecosystem processes, understanding ecosystem processes is pivotal for assessing ecosystem service. An ecosystem includes all the organisms living in a particular area, and all the non-living, physical components of the environment with which the organisms interact, such as air, soil, water and sunlight (Odum, 1971). From the standpoint of valuing an ecosystem, an ecosystem can be interpreted as interactions between biological organisms and environment which as a whole can output services at various temporal and spatial scales.

The ecosystem service assessment is a subjective process. The assessment result can change with the distance of the ecosystem to a population centre, the fragmented nature of an ecosystem, the purchasing power of people and the spatial scale (Konarska et al., 2002). Biological productivity capacity of an ecosystem varies with product volume, as well as human's preference, harvesting technique and processing technique.

The organizing function of an ecosystem is complex to analyse since functions vary spatially. For example, forest is effective in conserving water supply, but the conserving efficiency changes with spatial scale. Lessening the flood risk involves only the interests of some specific regions. Some ecosystem services, such as N, P and CO_2 cycling, occur only at global scales and analysis over smaller scale is not entailed.

The process of calculating ecosystem service is constrained by lack of a standardized framework and methods (Post et al., 2007). Data utilized in calculating ecosystem service are often in incompatible scales with the ecosystem service itself and non-standardized methods or data would result in different conclusions (de Groot, 2002). There are two conventionally used ecosystem service calculation paradigms. The first is to extrapolate estimated results of a few habitat types to entire regions or the entire planet (Troy and Wilson, 2006; Turner et al., 2007). The second is to focus on a single service in a small area (Kaiser and Roumasset, 2002; Ricketts et al., 2004). The first paradigm is limited in that spatial heterogeneity within one type of habitat is not considered; the second one fails to include the scope (number of services) and scale (geographic and temporal) which are critical for most policy questions (Nelson et al., 2009). Ecosystem service evaluation related to certain specific ecosystems or nations is inadequate to characterize the ecosystem at the global scale. Evaluation at any scale can benefit from the evaluation at higher or lower hierarchy scale (Millennium Ecosystem Assessment, 2005).

As remotely sensed images are becoming increasingly available for global coverage and at a continuous temporal scale, they become an important data source for calculating ecosystem service. These images have the advantage of providing spatially explicit information that is readily accessible, as required in assessing ecosystem services, such as land use and land cover, areal extent of each land use type, etc. As a result, the ecosystem functions, goods and service can be evaluated and reported in a spatially explicit manner. A summary of large-scale ecosystem service entails remotely sensed raster data, whose resolution will affect ecosystem service calculation significantly. The various resolutions of remote sensing data might alter the extent of fragmented land cover or leads to disappearance of certain land-cover types (Turner et al., 1989; Moody and Woodcock, 1994). The extent and the land-cover types normally determined from remotely sensed data can significantly influence the ecosystem service values. When remotely sensed land cover is used as a proxy for ecosystem service, the spatial scale at which the land cover is measured significantly influences measurements of both the ecosystem service extent and its valuation (Konarska et al., 2002). Results for individual trees can only be identified with fine-resolution data. On the other hand, fine-resolution data can identify the small coverage area, such as a small lake corner or a narrow river. Then extent of these complex landscape bodies will be expanded by fine-resolution data. Consequently, the related ecosystem services will be increased. For example, NOAA-AVHRR imagery and National Landcover Dataset (NLCD) are the two commonly used remote sensed imageries that have entire US coverage. The prior one has a spatial resolution of 8 km and the latter has a spatial resolution of 30 m. When they were used in calculating total ecosystem service value of the USA, it was found that ecosystem service in all states except New Mexico had higher ecosystem service values when measured in NLCD data than AVHRR data. The total ecosystem service value of the USA measured using fine-resolution data is 198% higher than measured using lower-resolution data (Konarska et al., 2002).

Ecosystem service management decision making is scale dependent

The interests that humans obtain from an ecosystem are highly related to its spatial and temporal scales. Ecosystem management should be in accordance with the characteristics of the ecosystem. The primary ecosystem service can only be realized at certain temporal and spatial scales, which means that ecosystem process and service is constrained to a certain extent and period. Ecosystem valuation results at a global scale are unable to meet the need of the policy making for a nation or a region. Appreciating the scale dependency of ecosystem service is pivotal for determining the interests of different stakeholders and establishing compensation payments to local stakeholders that face opportunity costs of ecosystem conservation. It is critical to make decisions on landscape-level conservation and management plans and ecosystem management at an appropriate institutional scale and implement ecosystem conservation and land-use planning (Tacconi, 2000). Separating ecosystem services into distinct scales is important in allocating interests appropriately to the stakeholders. Examples are determinations of the forest area in a watershed that help maintain clean water downstream, distribution pattern of natural habitat patches that provide pollination and pest control services for crops, effect distances of adjacent land uses that affect the capacity of forest and soil ecosystem to purify water (Houlahan and Findlay, 2004). All these services need to be assessed at their corresponding scales.

Ecosystem service types

Ecosystem service can be broadly classified as operating on local, regional, national or global scales (Kremen, 2005). For example, pest controls in crops using native parasitoids and predators conventionally operate at a local scale, while forest contributions to carbon sequestration function at a global scale. Ecosystem services value can be categorized into four types (de Groot et al., 2002; Hein et al., 2006):

1 Direct-use values are all production services and some cultural services (such as recreation) that human can utilize directly (Pearce and Turner, 1990). Typical examples include the wood timber produced by forest, fruits and water (Balick and Mendelsohn, 1992; Pearce and Moran, 1994). Cultural services can be exemplified as benefits people obtain from actual visits, recreation, cognitive development, relaxation and spiritual reflection (Aldred, 1994).
2 Indirect-use values arise from the positive functions provided by ecosystems that humans can utilize indirectly (Munasinghe and Schwab, 1993). The indirect-use value is commonly related to the regulation service provided to society, such as water conservation, carbon sequestration, erosion and flood control, regulating climate, hydrological and biochemical cycles, earth surface

processes and a variety of biological processes which account for a significant proportion of ecosystem service (Tobias and Mendelsohn, 1991; Chopra, 1993; Smith, 1993).

3 Option values are characterized by the willingness to pay in order to keep the option of using a resource in the future (Pearce and Turner, 1990). Ecosystem service is temporal-scale dependent, which means that actual and potential future services provided by ecosystems need to be considered in the valuation (Maler, 2000). A future resource can be any current ecosystem service value.
4 Non-use values can be considered anthropocentric (such as natural beauty), or ecocentric (e.g. relating to the notion that animal and plant species may have an existence right) (Hargrove, 1989) and are inherent to the ecosystem (Van Koppen, 2000). Non-use values vary with the moral, aesthetic and other cultural perspectives of the stakeholders involved. Kolstad (2000) further divides non-use value into three categories: existence value, altruistic value and bequest value.

Some agents provide services related to several values. For example, water provides materials related to human daily lives, such as freshwater and fishes, etc. In addition, freshwater provides a range of services related to regulating services and cultural services, such as tourism, natural flood control and erosion control (Van Jaarsveld et al., 2005).

Each category has a distinct scale-dependent feature. Production service can be accounted for by quantifying the flows and goods harvested in the ecosystem in a physical unit. The regulation service entails spatially explicit analysis of the biophysical impact of the service on the environment in or surrounding the ecosystem. For example, fire impact and hydrological services of a forest need to be evaluated across scales. Carbon sequestration service is an exception that is not scale dependent.

Ecosystem service studies need to consider scale

The multiscale feature of ecosystem services is becoming more evident in the increasingly interconnected global economy environment. Ecosystem services provided at one location can have important implications in far away places. As environmental effects on ecosystem service may be uncorrelated across scales, studies should be ideally carried out at multiple, nested scales (Sayer and Campbell, 2004). Ecosystem service research conventionally treats an ecosystem as an integral entity, while the spatial heterogeneity within an ecosystem is ignored. Ecosystem services can move out of the ecosystem boundary and generate services in areas beyond the system. For example, water conserved by forest in an upper river area can generate ecosystem service outside the forest. The water leaving the system can be used to generate power and irrigate farmland in a downstream area. One type of ecosystem process can generate various types of ecosystem services. Some types of ecosystems services are realized by certain ecosystem processes in the same spatial range. Some ecosystem services can be accumulated in the process of ecosystem processes being converted into ecosystem services, and the accumulation process might involve the spatial shifting from within the ecosystem to outside. In addition, the spatially heterogeneous structure within an ecosystem entails the spatially explicit information as revealed in the ecosystem service result. The spatially heterogeneous features of ecosystem service, including within and outside the ecosystem entity, underpins the necessity for accurately identifying, quantifying and spatially locating it in achieving the goal of precisely valuing the ecosystem service.

Recently, research evaluating ecosystem service across spatial and temporal scale has been increasingly reported (Holmes et al., 2004; Swift et al., 2004; Van Jaarsveld et al., 2005; Yue et al., 2005; Zhang and Lu, 2010). The study conducted in the 20 000 km^2 Ruoergai Plateau Marshes in the northeastern fringe of Qinghai-Tibetan Plateau found that the ecosystem service value of gas regulation and water regulation accounts for 49.9% and 45.6% of the total ecosystem service value, respectively. While the other ecosystem service items, including livestock products, waste treatment and recreation, account for only 4.5% of the total (Zhang and Lu, 2010). The dominance of regulation service is related to its strong water-holding capacity and carbon sequestration capacity. The extremely harsh living condition makes the marshes less suitable for producing goods to support human life. Another study assessing ecosystem service across spatial scales in the De Wieden wetland in the Netherlands concluded that goods production service, including reed and fish provision, accounted for 14% of the total ecosystem service value. Recreation accounts for 37% and nature conservation accounts for 49% of the total (Hein et al., 2006).

A city can be developed to provide a balanced proportion of each category of ecosystem service. Shenzhen is a typical city in China that experienced rapid development from a village of hundreds of residents since the opening of China to the world. Now the total land area of Shenzhen is 0.19 million ha and the total population is 10.4 million. In 2004, the woodland, cropland, wetland and built-up land accounted for 31%, 18%, 10% and 43% of the total land, respectively. The ecosystem services of water supply, waste treatment and food and raw material provision at the scale of Shenzhen city accounted for 64% of the total, while the ecosystem services at the province scale, including waste treatment and recreation, accounted for 7% of the total. The ecosystem services related to the global scale, including gas and climate regulation, biodiversity protection and recreation, accounted for 29% of the total (Li et al., 2010).

Case studies

Scale dependence of ecosystem service, as discussed above, is illustrated with two cases that consider different ranges of scales and different types of service. The first is a large, polluted, former brownfield site located in Liberty State Park (New Jersey, USA), which developed into an unmanaged wild area and represents a small-scale island of wildland within an urban, metropolitan landscape. The second is the Qinghai-Tibet Plateau (QTP), China, which represents a case in a natural and wild area at an ecoregion scale.

Liberty State Park Interior

Liberty State Park (LSP) Interior is an approximately 100-ha brownfield wild area located in Jersey City, NJ (40° 42′ 16, 74° 03′ 06). For much of the twentieth century, the site at LSP was used as a rail yard and experienced heavy industrial use while acting as a major hub for New York City. By the late 1960s, the rail yard was abandoned and since then the wild area of LSP has undergone a natural, unaided succession that resulted in a diverse mosaic of plant communities. Today, at first glance, the site appears to be a fairly healthy urban ecosystem consisting of a rather eclectic collection of early and mid successional habitats, including shrublands, pioneer hardwood forested wetlands, emergent marsh and more open forb-dominated old field communities and grasslands (Gallagher et al., 2008, 2011). Because of this variety in habitat and the large area of contiguous open space in the middle of a dense urban environment, LSP supports a diverse fauna and flora (US Army Corps of Engineers, New York District, 2004) and there is little doubt that LSP has an integral role in supporting wildlife in the greater New York City area. Thus this area developed into what we define here as an 'urban wildland', an urban habitat initially created by human impact (e.g. by severe disturbance) that either developed naturally and unaided and/or is now in a state of wild (i.e. has no or little direct, continued human impact).

A research team, consisting chiefly of scientists from Rutgers University, is currently investigating the ecosystem functions and their services of this urban wildland with the ultimate goal of developing a ecosystem service metric typical for and usable in urban areas in general (Hofer et al., 2010) For this, the research concentrates on the following services: (1) islands of biodiversity in a matrix of 'urban desert', oasis effects; (2) bioclimatology: amelioration of urban heat islands and air pollution; (3) wildland vegetation as carbon sinks; (4) ground water: improvement of infiltration and filtering functions of urban wetlands; (5) soil amelioration; (6) spaces where natural processes continue to work, including evolutionary processes; and (7) human interface: place for contact with nature and natural processes.

The ecosystem service of urban green space can be realized mostly in providing islands of biodiversity, ameliorating urban heat island effect and air pollution, sinking carbon and providing places for human contact with nature and natural processes. In many cases, an area of urban green space of the same size as an area of rural land can provide a much larger ecosystem service in such aspects as maintaining biodiversity. By definition, urban areas are characterized by strong human impacts. As such, urban ecosystems are expected to be impoverished in species richness compared to regions where human impact remains relatively low (McKinney, 2002). That urban areas, however, can harbour a relative large number of wild species comes for most people, urban and rural dwellers alike, as quite a surprise. Plant species richness and evenness of plant communities often increase in urban environments as compared to rural areas (Hope et al., 2003; Marzluff, 2005; Grove et al., 2006). This appears to be due to high spatial heterogeneity of urban habitats in combination with introductions of non-native, but urban-adapted species (Grimm et al., 2008). Bird diversity as well can increase due to limited urbanization (Marzluff, 2005). This is mainly the consequence of the opening of homogenous, natural habitats such as forests. It can be shown that the green spaces set aside from overly strong anthropogenic pressures (vacant lands, less frequented and less manicured parts of parks, public rights-of-way, residential yards, etc.) act as biodiversity hotspots that contribute to the ecological functions of urban areas. Besides providing such basic ecosystem service functions, these areas provide the unique opportunity for nature–human contact even in cities (Dunn et al., 2006; McKinney, 2006; Grimm et al., 2008). Such contacts are being increasingly recognized as crucial for the welfare of urban humans, as demonstrated by a recent correlations of health aspects with exposure to natural environments (Mitchell and Popham, 2008).

The wildland of LSP is an example of a species-rich island in a matrix of low diversity within a sea of low diversity typical for the built-up and developed urban matrix. Table 7.1 provides an overview of this biodiversity concentration for a number of plant and animal taxa. Table 7.1 illustrates that the precipitous differences in species richness and therefore biodiversity between wildland and urban matrix is consistent between scales. Regardless of whether one considers small-scale community level (here 1000 m^2), metacommunity scale (here 200 ha) or regional scale (state wide scale = 22 590 km^2), wildlands tend to harbour much larger biodiversity. Such scale-independent differential effects when considering intensively human-used patches and landscape with lesser-used sites has been noted before (Savard et al., 2000). Table 7.1 provides an overview of this biodiversity concentration for a number of plant and animal taxa. Currently, a frame-work is being developed to assess a network of wildlands on different scales. New Jersey is an ideal proving ground for such studies as the state has a sizable percentage of vacant, postindustrial sites (Lurie and Wacker, 2009). As such, the work will allow meaningful comparisons with other industrialized region of the world.

Table 7.1 Scale-dependent richness within the urban wildland of Liberty State Park and the surrounding matrix. These numbers are preliminary and unpublished data, provided and assembled by a variety of sources and authors; regional data are estimates. Only regularly occurring species are included.

Taxa	*Liberty State Park*		*Urban matrix in New Jersey*		*Region: New Jersey, urban, % of state*	*Region: New Jersey, undeveloped Urban, % of state*
	0.1 ha	200 ha	0.1 ha	200 ha	26.3%	1.1%
Vascular plants	20–65	185	6–12	45	210	560
Birds	8–17	87	4–7	21	45	210
Mammals	2–8	11	2–4	6	17	45
Odonata	5–7	12	1–3	6	14	35
Lepidoptera (butterflies)	12–14	25	4–5	11	24	50

Qinghai-Tibet plateau

Qinghai-Tibet plateau (QTP) is the largest and highest plateau in the world. It covers about 2 500 000 km^2 and hosts about 8 000 000 people. Qinghai-Tibet plateau has a unique feature in terms of ecosystem service since its global and continental ecological services have a much more significant meaning than the goods it provides. QTP ecosystem plays an important role in regulating atmospheric chemical composition because forest and grassland can be a huge sink or source for such atmospheric gas as CO_2 and O_2 etc. The critical role of QTP in regulating climate stems from its extensive areas and high plateau. Due to its existence, the area lying to the east of QTP in mid-latitude China receives more rainfall than other areas in the mid-latitudes of the world. There are 29 182 km^2 of lakes and 65 548 km^2 of glaciers. The vegetation, lakes and glaciers set the stage for the critical role of QTP in supplying and regulating water for China and other southern Asian countries.

The ecosystem services that the QTP can provide include: (1) food production and provision of raw materials; (2) the provision of opportunities for recreation and culture; (3) generic resources; (4) waste treatment; (5) soil formation and reserve; (6) water regulation and supply; (7) global climate regulation; and (8) atmospheric gas regulation.

The QTP ecosystem services include the provision of goods in the form of grass for livestock grazing and agricultural products to local residents, which form the livelihood of the people. The QTP ecosystem produces 1 790 000 tons of food supply, 345 950 tons of oil, 438 750 tons of meat and 419 700 tons of milk. The total provision of goods and food amount to about 623 × 10^8 Chinese yuan, which accounts for only 6.5% of the total ecosystem service values (Table 7.2).

Table 7.2 Qinghai-Tibet Plateau: ecosystem service values for each service item (10^8 yuan year^{-1}) (based on data from Xie et al., 2003)

	Forest	*Grassland*	*Farm land*	*Wetland*	*Water body*	*Desert*	*Total*
Gas regulation	470	500	13	5	0	0	988
Climate regulation	362	562	24	50	12	0	1010
Water regulation and supply	430	500	16	46	526	25	1543
Soil formation and reserving	523	1218	39	5	0.3	17	1802.3
Waste treatment	176	818	44	54	469	8	1569
Genetic resources	438	681	19	7	64	286	1495
Food production	13	187	27	1	3	8	239
Raw materials	349	31	3	0.2	0.3	0	383.5
Recreation and cultural	172	25	0.3	16	112	8	333.3

The unique natural beauty, history and culture of the area attract millions of tourists each year. The opening of Qinghai-Tibet railway greatly improved the transportation conditions to Tibet and the number of tourists visiting Tibet is increasing rapidly each year. In 2002, the recreation and cultural ecosystem service value reached 333.3×10^8 yuan, and this number has been increasing annually. In 2009, the Xizang and Qinghai provinces lying in the Tibet plateau attracted over 12 millions of Chinese and foreign tourists.

The ecosystem services with continental and global significance, including atmospheric gas and global climate regulation, and water regulation, soil formation and genetic resources account for 73% of the total. QTP, as the 'roof of the world' is the largest 'water tower', from which many of major river systems originate. It hosts unique biodiversity in the high plateau area. Due to its unique high altitude, mountainous topography and climatic conditions, there are large number of species that found refuge during the ice ages and a number of new species evolved in situ, all of which contribute to a rich genetic resource. The relatively young geological history and the extreme high plateau climate make soils in the QTP high plateau diverse and unique. They also serve as huge reserves of plant nutrients.

Tibet is a typical case that has regional, continental and global ecosystem service significance and the continental and global ecosystem service might have higher significance than the local one due to its ecological significance to the region and globe. At the intrinsic scale, the interests of the local stakeholders of QTP are related mainly to raw materials provided and food production. At a national scale, the interested stakeholders will consider recreation and cultural, water regulation and supply, and waste treatment. At a continental scale, the gas regulation and climate regulation, soil formation and reserves, and genetic resources functions of QTP play a critical role. In addition, the gas and climate regulation function and the genetic resources function have a global impact considering the wide-ranging effect of QTP.

Conclusions

Ecosystem service is scale dependent as revealed by the scale-dependent ecosystem service provider, scale-dependent beneficiary and management. Here, ecosystem service are exemplified in hierarchical levels as characterized in the various types of ecosystem service provided by a park in a metropolitan New York area and the nature-dominated Tibet plateau. To effectively manage and fully utilize ecosystem service of each ecosystem, we need to understand the scale dependency of ecosystem functions. This work was supported by the "One Hundred Talent Plan" of Chinese Academy of Sciences.

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