CHAPTER 17

# Human-Nature Interactions over Distances

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## 17.1 Introduction

Human–nature interactions are key factors shaping global sustainability and human well-being. They have been widely studied within a particular area, but the world has become increasingly connected over distances, both socioeconomically and environmentally. Distant interactions such as trade, migration, and spread of invasive species are now more widespread than they ever were before (Liu et al., 2013a). For instance, human societies obtained much of their food, water, and fuel locally in the past, but now increasingly rely on sources at opposite ends of the Earth via global trade (Kastner et al., 2011, Konar et al., 2011). Global food exports have increased tenfold over the past several decades (United Nations Statistics Division, 2012). Water scarcity has also led to large-scale water transfer schemes, such as China's South-North Water Transfer Scheme, which aims to transfer 45 billion $m^3$ of water across the nation each year (Liu and Yang, 2012). These distant interactions have profound implications for sustainability and human well-being, often exacerbating social and environmental problems such as climate change, famine, land degradation, species extinctions, and social unrest (Liu et al., 2013a).

These and other distant connections have often been separately studied. For example, studies on climate teleconnections concentrate on linkages between climate systems that are hundreds and even thousands of kilometers apart (Avissar and Werth, 2005) but largely ignore relevant socioeconomic linkages. On the other hand, studies on economic globalization (e.g., Levitt, 1982) focus on distant socioeconomic relationships. They pay relatively little attention to environmental interactions, although there have been some separate recent studies on greenhouse gas (GHG) emissions associated with trade (Peters et al., 2011). Furthermore, previous studies often treat distant factors as drivers of changes in a particular area (e.g., DeFries, 2010, Lambin and Meyfroidt, 2011, Stevens et al., 2014). But little research has been done on the feedback and impacts on other areas (Folke et al., 2011). While previous studies provide useful information, the results may be incomplete or partial. This shortcoming occurs due to the lack of simultaneous consideration of distant socioeconomic and environmental interactions, feedbacks, impacts beyond the systems being focused on, and relationships among various distant linkages.

To address these crucial issues, umbrella concepts need to be developed to bring together multiple different interactions and disciplines. A prominent example of the umbrella concept is ecosystem services (Daily, 1997), which include diverse benefits that nature provides to humans (e.g.,

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water and air quality, nutrient cycling, and spiritual and recreational benefits). Another good example is the environmental footprints concept, which integrates different types of human impacts on nature (Hoekstra and Wiedmann, 2014).While these and other umbrella concepts are valuable, none of them is able to systematically integrate human–nature interactions that occur over distances.

A new framework of telecoupling (socioeconomic and environmental interactions over distances) has been proposed to facilitate such integrated research (Liu et al., 2013a). The framework (Liu et al., 2013a) treats each place as a coupled human and natural system in which humans and natural components interact (Liu et al., 2007). It provides an explicit approach to account for and internalize socioeconomic and environmental externalities across space. The framework consists of five major interrelated components (coupled human and natural systems; flows of material, information, and energy among systems; agents that facilitate the flows; causes that drive the flows; and effects that result from the flows; Liu et al., 2013a). Depending on the direction of flows, systems can be classified as three different types. They include sending systems (e.g., exporting countries), receiving systems (e.g., importing countries), and spillover systems (e.g., countries other than the trade partners). Spillover systems are those that affect and are affected by the interactions between sending and receiving systems. A single system can be classified as one type of system for one telecoupling and another type of system for another telecoupling. For instance, a city can be a receiving system for food and be a sending system for industrial products. Within each coupled system, there are internal or local couplings. The framework also explicitly considers feedbacks (e.g., human–nature feedbacks within a coupled system and across telecoupled systems). There has been increasing interest in the telecoupling framework. For example, the framework has been conceptually applied to land change science (Eakin et al., 2014, Gasparri et al., 2015, Liu et al., 2014); species invasion (Liu et al., 2014); payments for ecosystem services programs (Liu and Yang, 2013); conservation (Carter et al., 2014, Gasparri and de Waroux, 2014); and the trade of food (Garrett et al., 2013), forest products (Liu, 2014), energy (Liu et al., 2015b), and virtual water (Liu et al., 2015b). However, there is a lack of quantification of the telecoupling framework.

To fill such an important knowledge gap, we apply the telecoupling framework to examine telecouplings between Wolong Nature Reserve (hereafter "Wolong") and the rest of the world. As stated in Chapter 3, Wolong is a 2000-km$^2$ protected area located within a global biodiversity hotspot (Liu et al., 2003, Myers et al., 2000) in southwestern China (Ministry of Forestry, 1998; Figure 17.1). It is a home of the endangered giant panda (*Ailuropoda melanoleuca*) and more than 6000 other animal and plant species. Wolong also encompasses approximately 5000 local residents, mostly farmers (State Forestry Administration, 2006) who grow crops, raise livestock, and collect timber and non-timber forest products (Li et al., 1992). In this chapter, which is largely based on Liu et al. (2015a), we analyze major components of several telecoupling processes. These include panda loans, tourism, information dissemination, conservation subsidies, and trade of agricultural and industrial products (Figure 17.1). We discuss their similarities, differences, and interrelationships. We chose these example processes due to their prominence in the coupled system of Wolong and their data availability, although there are also other telecouplings (e.g., labor migration from Wolong to cities; Chen et al., 2012; Chapter 11) which may also interact with these analyzed in this chapter.

## 17.2 Telecouplings

### 17.2.1 Panda loans

Wolong is a stronghold for the wild giant panda population. It is also home to the China Conservation and Research Center for the Giant Panda (CCRCGP), a research and captive breeding base that houses over 200 pandas, the largest captive population in the world. The panda loan program enables zoos inside and outside China to borrow pandas from the center over extended periods of time (from one to many years) and generally involves the payment of a fee. The total number of panda loans from Wolong to other places in China and other countries increased from fewer than 20 in 1998 to 85 in 2010. There was a total of 63 new panda loans between 2004 and 2010 (Figure 17.2A).

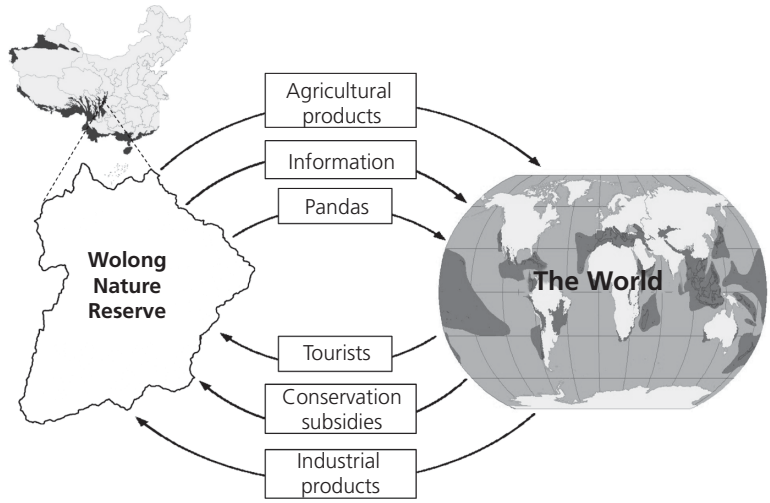


**Figure 17.1** Schematic illustration of telecoupling processes between Wolong Nature Reserve in southwest China and the rest of the world. Shaded areas represent global biodiversity hotspots (Conservation International, 2011). Adapted from Liu et al. (2015a).

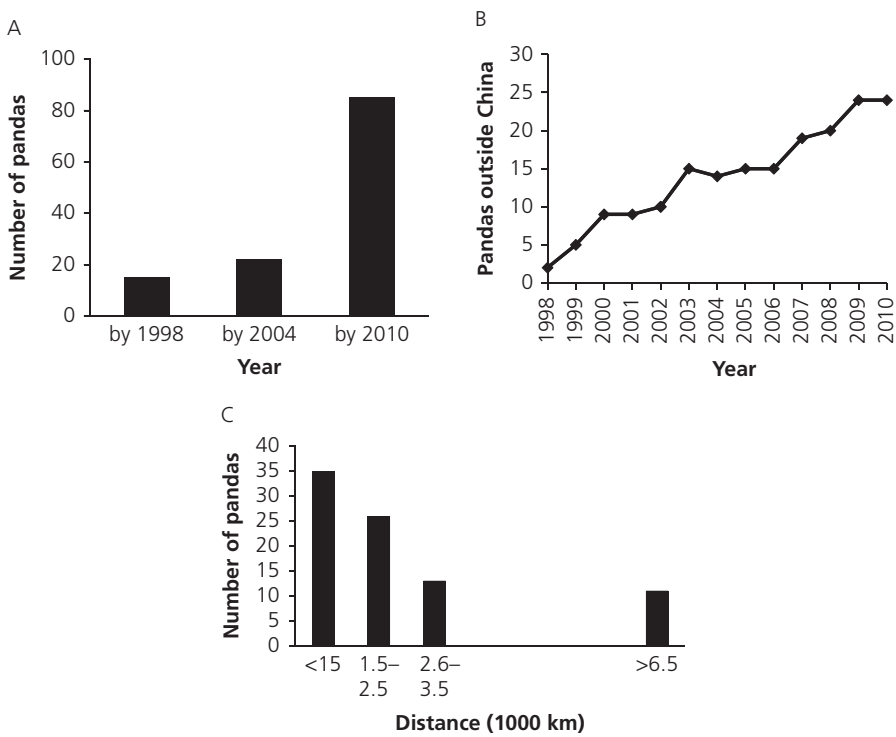


**Figure 17.2** (A) Temporal changes in the number of giant pandas transferred from Wolong to other areas of China on loan; (B) temporal changes in the number of giant pandas transferred from Wolong to outside China on loan; (C) distances between Wolong and zoos hosting pandas from Wolong. Adapted from Liu et al. (2015a).

### Telecoupled systems

In this case, the sending system for pandas is Wolong. The receiving systems are zoos inside and outside China, such as the Beijing Zoo, the San Diego Zoo, the National Zoo in Washington DC, and zoos in Europe (e.g., London) and in Asia (e.g., Kobe). A total of 22 cities in mainland China, Hong Kong, and Taiwan received at least one panda from Wolong, with Guangzhou hosting the largest number (i.e., ten; Figure 17.3). Furthermore, Wolong's pandas were sent to seven cities in five other countries (Japan, Australia, USA, Thailand, and Austria). A total of 12 went to Japan and seven to the United States in 2010 (Figure 17.3). The spillover systems are many, including areas from which people travel to see the pandas in those receiving systems. Spillover systems also include areas that provide funding for the loans, grow bamboo to feed the pandas, and are affected by other activities related to panda loans.

### Agents

The agents include people and organizations that make panda loans possible. In the sending system, agents include the China Society for Wildlife Conservation and the State Forestry Administration that develop policies and agreements. Another agent is the Wolong Nature Reserve Administration Bureau that implements the policies (e.g., it selects which pandas are to be loaned). In the receiving systems, agents include people and organizations that lobby and find resources for panda loans. Zoos often seek

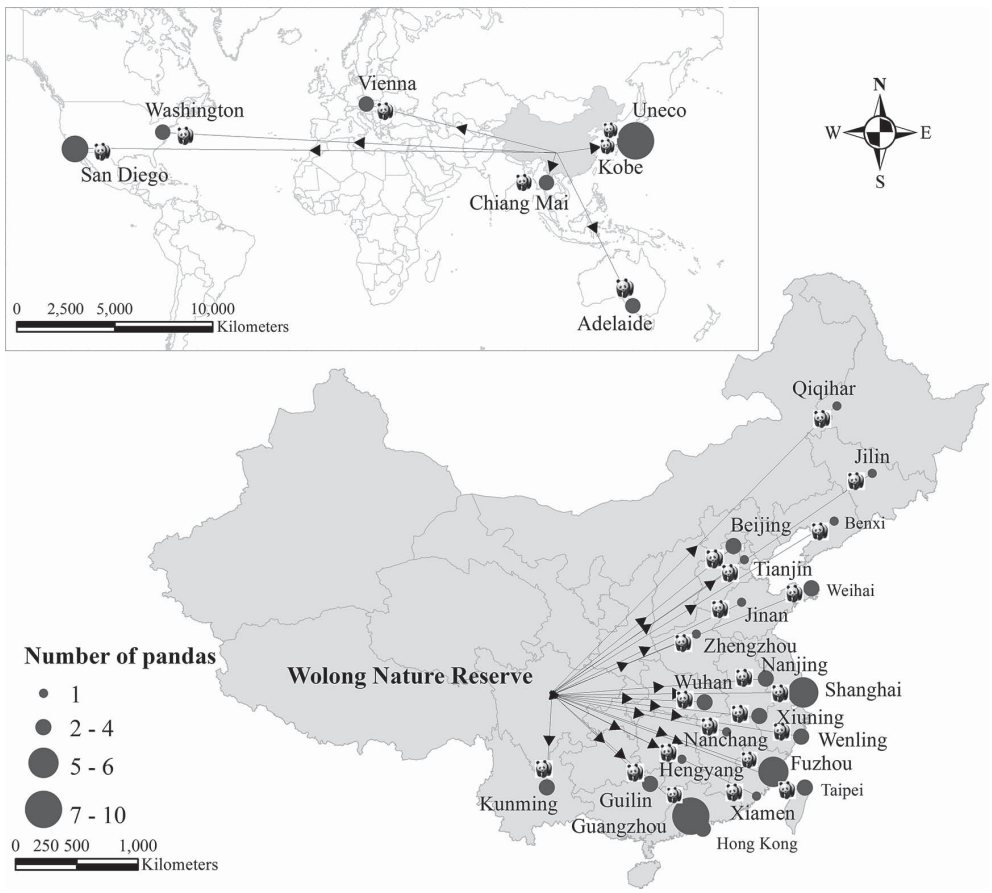


**Figure 17.3** Spatial distributions of pandas loaned to zoos outside Wolong (in China and in other countries). Adapted from Liu et al. (2015a).

corporate sponsors to help fund the loans (*National Post*, 2010). There also may be agents from the spillover systems outside Wolong and the receiving systems that help negotiate panda loans. Negotiations often involve individuals with high-level positions in receiving countries' governments. For example, the Prime Minister in the UK visited China, while China's Vice Premier traveled to the UK as part of the negotiations on the panda loans to the Edinburgh Zoo (*The Guardian*, 2011).

### Flows

The flows include the movement of pandas and people involved in the panda loans. The number of panda loans to other countries increased from two in 1998 to 24 in 2010 (Figure 17.2B). The numbers of pandas and the distances between Wolong and the receiving systems show non-linear relationships. Within 3500 km, as distances increase, the numbers of pandas decrease (Figure 17.2C). There were no pandas in places between 3500 km and 6500 km from Wolong, but beyond 6500 km the numbers of pandas increased (Figure 17.2C). Regarding flows of people, panda experts from Wolong provide training to the staff in the receiving systems. The information flows include exchanges of agreements and, in many cases, money transactions (fees amount to US$1 million per panda pair per year).

### Causes

The causes behind panda loans include a variety of factors. The receiving systems have strong interests in pandas due to a long history of cultural affinity and fascination with the charismatic panda worldwide (Ellis et al., 2006, Schaller, 1994). Interest in scientific research has also grown in the last several decades due to many unique aspects of the panda's biology. Examples include the panda's adaptation to bamboo, narrow reproductive estrus window, and scent communication (Swaisgood et al., 2009). As threats to the panda's wild population increase, the impetus also increases to establish a sustainable population of captive pandas. These pandas could theoretically be used for population rescue via reintroduction (Wildt et al., 2006). A technological cause is rooted in recent improvements in captive breeding and infant care that have allowed for a tripling of the captive panda population from 1970 to 2000 (Zhang et al., 2006). Such success has allowed for more individuals to be available for loans. There are also economic causes in both sending and receiving systems, as zoos can substantially increase their visitation rates, which translate into gains of millions of dollars. The sending system can also be spurred to participate due to expected economic benefits through the loan deals (Buckingham et al., 2013). In addition, there is political will for panda loans by relevant leaders (Buckingham et al., 2013).

### Effects

There are both environmental and socioeconomic effects in the sending, receiving, and spillover systems. The socioeconomic effects include publicity about sending and receiving systems, and economic benefits from panda loans. Costs of keeping pandas in zoos are considerable, as the construction of new facilities for one pair of pandas alone (e.g., indoor/outdoor enclosures, specialized heating/cooling systems, and educational exhibits) cost US$10.3 million at the Adelaide Zoo and US$14.5 million at the Toronto Zoo (Buckingham et al., 2013), in addition to operational costs. For the spillover systems, those visiting pandas in the receiving systems pay for entrance fees and travel costs. Visitors to the National Zoo in Washington DC to see pandas come from not only the USA, but also many other countries (Smithsonian National Zoological Park, 2012).

In addition, new panda loans improve social networks for scientific collaboration across countries via participation in international networks such as the Conservation Breeding Specialist Group (Wildt et al., 2006). The environmental impacts include awareness of the importance of panda conservation (Ellis et al., 2006, Schaller, 1994) by residents in sending, receiving, and spillover systems. A lesser known environmental impact on the receiving system is the large amount of bamboo required to sustain captive pandas (up to 32 kg per day per panda). Zoos often establish bamboo plantations to meet this large and specialized food requirement. Edinburgh Zoo imported bamboo from Holland (a spillover system) at over US$100 000 per year (Brown, 2011, Buckingham et al., 2013). Other zoos seek to collaborate with local citizens to grow bamboo on their properties (Buckingham et al., 2013).

Another environmental impact is the $CO_2$ emissions of transporting pandas from sending to receiving systems as well as of tourists traveling to see the pandas in the receiving systems. For example, a Boeing 777 jet flight emits roughly 29 kg of $CO_2$ per km (BlueSkyModel, 2014). Given the 8000-km distance between Chengdu and Edinburgh, Scotland (a recent receiving system), transporting a pair of pandas in a Boeing 777 could emit 232 000 kg of $CO_2$ one way. However, Edinburgh did not have enough bamboo to support the pandas for the trip. Therefore, they financed a US-operated plane originating in Memphis, Tennessee, to fully load up with bamboo and then travel to Chengdu to pick up the pandas prior to the Edinburgh leg (BBC, 2011), an additional 12 550 km and over 360 000 kg of $CO_2$. The amount of $CO_2$ emissions caused by tourists may vary depending on the distance and mode of traveling. But emissions from tourism would be less per capita than a panda because several hundred tourists can travel on one plane, while one or two pandas take up an entire plane on their own. For example, a passenger traveling in economy class from Detroit, USA, to Beijing, China, and then Chengdu, China (the closest airport to Wolong) would generate roughly 1705 kg of $CO_2$ (International Civil Aviation Organization, 2014).

Feedbacks from panda loans are many. For example, the first pair of pandas sent to the National Zoo in Washington DC garnered such widespread appeal that a second pair of pandas was later sent after the first died. Some of the revenues from panda loans have been targeted for panda conservation in the sending system and spillover systems in other areas of panda habitat. Receiving systems have also undertaken capacity-building endeavors in Wolong, sending experts to both train and learn from Wolong's scientists. On the environmental side, the continued interests in panda loans have raised concerns about the well-being of captive pandas, and there were appeals and discussions to limit the number of panda loans (Schaller, 1994).

### 17.2.2 Tourism

Tourism is one of the largest industries in the world (World Travel and Tourism Council, 2014). With nearly 266 million direct jobs, tourism and its related economic activities produce 9.5% of the World Gross Domestic Product with almost one billion international travelers in 2013 (World Travel and Tourism Council, 2014). Nature-based tourism (focused on observing and appreciating nature) has been the fastest growing sector of tourism since the 1980s (Newsome et al., 2002). To meet the increasing demands for nature-based tourism, many nature reserves around the world have hosted tourists. For example, by the late 1990s ~80% of nature reserves in China had developed ecotourism (a type of nature-based tourism). Almost 16% of the nature reserves each hosted more than 100 000 tourists annually (Chinese National Committee for Man and the Biosphere, 1998, Li and Han, 2001). Like many other nature reserves, Wolong has attracted a large number of tourists since the early 1980s (Liu, 2012).

#### Telecoupled systems

For tourists, Wolong is the receiving system. The sending systems are the places in the rest of the country (for domestic tourists, Figure 17.4) and the rest of the world (Figure 17.5) where tourists visiting Wolong originate. During the summers of 2006 and 2007 we surveyed tourists visiting captive pandas held at the CCRCGP in Wolong. Our tourist surveys indicated that more than half (651) of the 1063 sampled tourists in 2006 and 2007 were from at least 30 provinces and cities in mainland China, Taiwan, and Hong Kong (Figure 17.4). While a large number of Chinese tourists lived in the province of Sichuan where Wolong is located (28.6%) and the neighboring municipality of Chongqing (15.8%), more distant provinces and cities were also represented. Guangdong (6.4%), Beijing (2.7%), and Shanghai (2.0%) also sent large numbers of tourists to Wolong. Internationally, we recorded 26 different countries of origin. The majority of international tourists were from Japan (13.4%), the USA (7.9%), the UK (5.0%), France (2.8%), and The Netherlands (2.6%; Figure 17.5). The spillover systems are areas in the rest of the world that support the supply chain industry of tourism. Spillover systems might also include the stopover cities along the travel route to Wolong, such as Beijing, Shanghai, and Chengdu, which provide services to tourists.

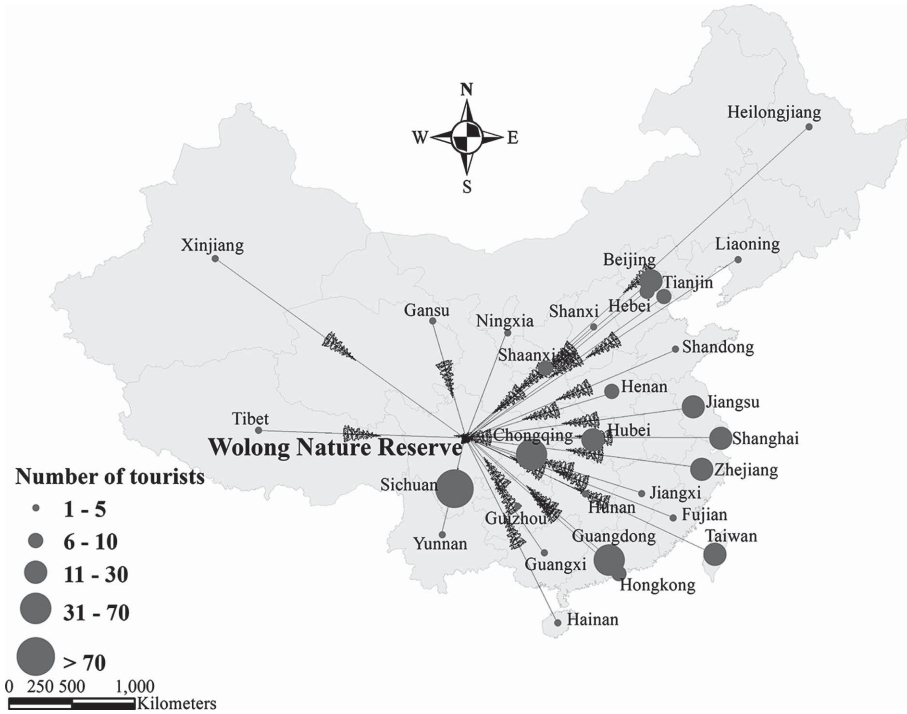


**Figure 17.4** Spatial distribution of sampled tourists to Wolong from other parts of China, 2006–2007. Adapted from Liu et al. (2015a).

## Agents

Diverse agents are involved in tourism in Wolong. They include government agencies and officials (e.g., Sichuan Tourism Bureau, Sichuan Forestry Department, and Wolong Administration Bureau) who develop and implement tourism policies. Other agents include tourism agencies that facilitate and attract tourists (e.g., Jiuzhaigou Scenic Area Administration, and investment companies such as Luneng Xinyi Ltd. Co., a subsidiary

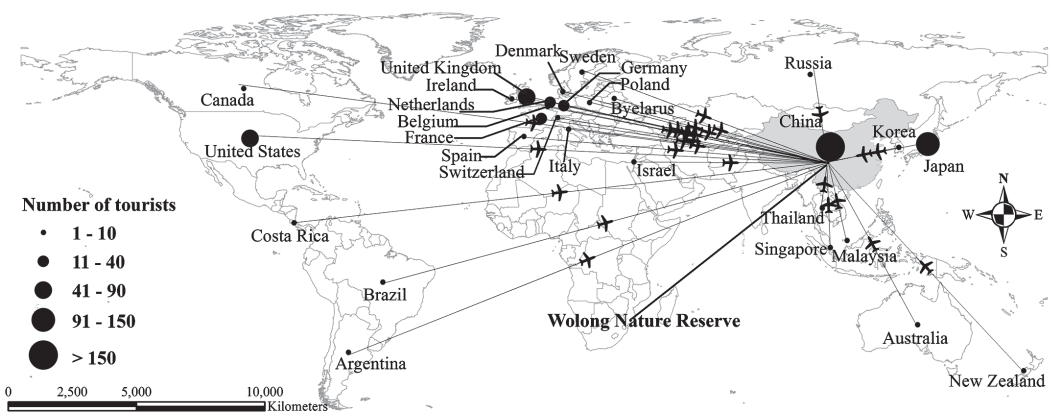


**Figure 17.5** Spatial distribution of sampled tourists traveling to Wolong from other countries, 2006–2007. Adapted from Liu et al. (2015a).

of a large state-owned enterprise in Shandong Province). Wolong Tourism Development, Inc., a government-owned company, was established in 1991 to organize and promote visitation to Wolong. In 1997, the company was converted into the Department of Tourism, an official governmental agency under the Wolong Administration Bureau, to be responsible for all tourism planning and management issues (Liu et al., 2015b). Agents in the receiving system also include local residents engaged in supporting the industry. Other agents in sending and spillover systems include those who arrange trips for tourists (e.g., tourist agents who make travel arrangements, foreign affairs officers who issue passports, and embassies and consulates general that issue visas). People who provide services to tourists in stopovers such as Beijing (for international tourists) and Chengdu (for international tourists and domestic tourists coming from outside Sichuan Province) are also agents.

### Flows

The number of tourists to Wolong increased dramatically over time (Figure 17.6A). Tourism started in the early 1980s and reached a peak in 2006, with an annual visitation of 220 000 visitors (Figure 17.6A). There was a drop in 2003 and a complete stop in tourism after the 2008 Wenchuan earthquake. For domestic

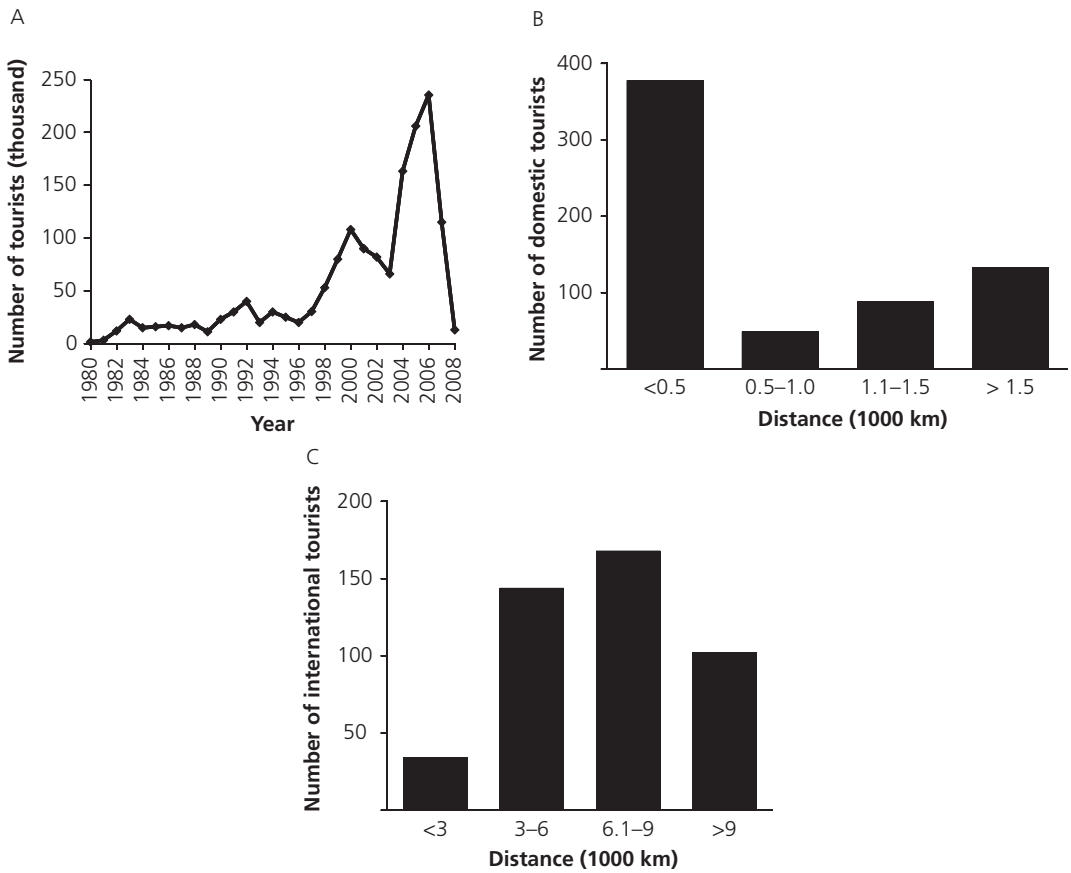


**Figure 17.6** (A) Changes in the total numbers of tourists to Wolong over time; (B) number of sampled Chinese domestic tourists at different distances between their origins and Wolong, 2006–2007; (C) number of sampled international tourists at different distances between their origins and Wolong, 2006–2007. Adapted from Liu et al. (2015a).

tourists, the largest number of visitors came from nearby areas (< 500-kilometer range, e.g., from Sichuan and Chongqing, Figure 17.6B). Beyond this distance, the number of tourists dropped markedly by 87% and then increased slightly with distance. For foreign tourists (Figure 17.6C), the largest numbers occurred at intermediate distances. Aside from tourists, money also flows into Wolong for tourism-related infrastructure. In 2002, for example, the Luneng Company in Shandong Province invested 42 million yuan to upgrade the Wolong Hotel to four-star level with 668 beds (Wolong Nature Reserve, 2005).

**Causes**

Tourism is affected by economic, political, technological, cultural, and ecological factors. On one hand, many local people in Wolong are enthusiastic about participating in tourism as they have a strong desire for income from tourism. Government agencies have been actively promoting tourism, and technological advances, especially communication technologies and transportation, have played important roles in promoting Wolong tourism. On the other hand, there are demands for nature-based tourism by people in other parts of China and the world. Wild pandas, natural forests and wildlife, and clean air and water were the top three reasons that motivated domestic tourists to come to the reserve. For international tourists, the top three were natural forests and wildlife, wild pandas, and pandas in captivity (Liu, 2012). Both external and internal disturbances shaped tourism over time. For example, the Severe Acute Respiratory Syndrome (SARS) epidemic occurring across China led to a drastic drop in the number of tourists in 2003 (Figure 17.6A). In 2008, the 8.0 $M_s$ Wenchuan earthquake completely stopped tourism (Figure 17.6A), as Wolong was near the epicenter of the earthquake. Most of the infrastructure was destroyed by this disaster and associated landslides (see Chapter 12). Destroyed infrastructure included tourism facilities and the main road connecting Wolong to outside markets. Furthermore, landslides have become much more frequent after the earthquake. The road has been repeatedly destroyed even after many rounds of repairs. As a result, so far tourism has not yet recovered.

**Effects**

There are a variety of socioeconomic and environmental effects of tourism. Here we use the data from 220 households in Wolong that we have sampled since 1998 to illustrate the socioeconomic effects of tourism in Wolong. The number of sampled households that directly participated in tourism-related activities increased from nine (4%) in 1998 to 60 (28%) in 2007. Approximately 77% of local rural households received income associated with tourism directly or indirectly (Liu, 2012). For example, a total of 116 households (including 87 households that were not directly involved in tourism) reported having received some income from temporary labor jobs on infrastructure construction. A number of households also reported having earned income from selling locally produced products such as local medicinal herbs (14 tourism households and 25 non-tourism households). Other households sold honey (6 tourism households and 19 non-tourism households), and smoked pork (10 tourism households and 12 non-tourism households). Some of these products were sold to restaurants, shops, and street vendors in Wolong, much of which was later sold to tourists. The locals used the remaining products themselves or sold them directly to tourists and markets outside Wolong. The composition of income between tourism households and non-tourism households differed substantially. For tourism households, direct and indirect tourism income was most important, and their non-farm income percentage increased from 40% to 66% between the late 1990s and mid-2000s (Liu, 2012). In contrast, non-tourism households generally earned more farm income, while their non-farm income percentage remained basically the same (~36% to 38%) from the late 1990s to mid-2000s. Furthermore, the development of tourism has motivated the community to upgrade local infrastructure. Tourism contributed to the transformation of Wolong's traditional subsistence agriculture economy into a diverse, modern, and more service-oriented one (He et al., 2008, Liu, 2012).

Environmental effects of tourism on the receiving system are direct or indirect. For direct effects,

tourists influence vegetation along trails. To estimate the impacts of tourists using trails on vegetation, we conducted field sampling along four main hiking trails in Wolong between June and August 2007. Sites ($n$ = 64)were sampled at regular intervals of 200–300 m. We found that there were more plant species occurring at trailsides than in the forest interior in the shrub, sapling, and seedling layers. Herbaceous species richness at trailsides was also higher than in the forest interior (Liu, 2012). This effect may be attributed to new niches opening up due to the disturbance created by people and livestock trampling the soil. Fecal deposition by livestock along trails also added nutrients to the soil (Liu, 2012).

Some tourists from all over the world also donate to Wolong after visiting to provide support for captive breeding and research, helping it to become the largest captive giant panda breeding center in the world. Besides regular donations in the form of cash and goods, donations are also delivered through an adoption program that allows donors to "adopt" a captive panda with the donated funds.

Tourists also have many indirect effects. The construction of roads, facilities, and other infrastructure has a negative impact on the local ecosystem (e.g., fragmentation of giant panda habitat; Hull et al., 2011). On the other hand, tourists affect the environment positively through altering the livelihoods of local residents. Some tourists purchase local products, create job opportunities (e.g., having locals as guides or employees at tourism facilities), and bring in new information (e.g., about markets, jobs, and technology). By helping to increase local residents' income, tourism has helped increase the affordability of electricity and thus reduce fuelwood collection in panda habitat. For instance, households engaged in restaurant or hotel operation were more likely to decrease their fuelwood consumption compared to those who were not (Liu, 2012). Engagement in nature-based tourism activities has enhanced local residents' awareness of conservation issues (Liu et al., 2012).

In terms of effects on sending systems, visits to Wolong may improve tourists' quality of life, e.g., enriching experience (Neal et al., 2007). Visits may also reduce household spending and environmental impacts in sending systems when tourists are away. Although travel by tourists leaves an environmental footprint (Gössling et al., 2002), it may also have positive environmental effects. For example, many residents from the city of Chengdu in Sichuan Province spend an extended period of the summer in Wolong due to its cool weather (Liu, 2012). If they switch off the air conditioners at their homes when they are away, they can reduce the consumption of energy and GHG emissions. However, the net impact is unknown due to unavailable data on GHG emissions from transport and other activities.

For the spillover systems, tourism creates economic benefits that ripple through the chain of tourism-related industries (Balmford et al., 2009). For instance, tourism-related industries outside receiving and sending systems benefit from selling goods (e.g., outdoor clothes and hiking boots) and providing services to tourists. On the other hand, GHG emissions as a result of both national and international travel contribute to global climate change and thus affect all systems, including the spillover systems.

Tourism also generates feedback effects. After tourists visit Wolong, they disseminate information to friends and colleagues, thus potentially affecting the probability of visits by others. The past success of tourism within Wolong also provides an incentive that has attracted a large amount of outside investment for further tourism infrastructure development. One example is the recent construction of a new captive panda breeding center (Hong Kong SAR Government, 2012). According to Wolong's Master Plan for 2015–2025, proposals have also been put forth for the construction of a large hotel and mushroom plantation to support future tourism growth (Sichuan Academy of Forestry, 2014).

### 17.2.3 Information dissemination

Wolong has become increasingly known both nationally and internationally through the news media and publication of books and articles, as well as through visitors. Of course, information is also constantly entering Wolong from the outside, but due to data constraints here we focus only on the information emanating from the system.

#### Telecoupled systems

Wolong is the sending system. The receiving systems are places that publish articles and books on,

create television programming about, and send visitors to Wolong. Spillover systems are other places that know about Wolong through reading relevant articles and books, watching the news or other programs, and receiving information from visitors to Wolong, as well as the Internet and social media.

### Agents

In the receiving system, the main agents are news media outlets and book publishers as well as authors in disseminating information about Wolong. For news media outlets, there are usually major national and international media organizations, such as *The New York Times* (Simons, 2003). Book publishers also include major international publishing houses, such as University of Chicago Press (e.g., *The Last Panda* by Schaller (1994)). A variety of scholars and reporters, as well as writers, have written articles about Wolong. Many news agencies have also created specials on television programs, such as short stories on *Good Morning America* and documentaries on nature channels such as *Animal Planet* (Feldon, 2008). In the sending system, local scientists, conservation organizations, reserve managers, and residents are the main agents in providing information to the news media organizations and publishers. In the spillover systems, the main agents are readers and audiences who read news articles and books or watch videos related to Wolong.

### Flows

Flows include the movement of information about Wolong and people who visited Wolong to collect such information. We examined the frequency of the phrase "Wolong Nature Reserve" in English books published since 1980 based on the n-gram corpus data set provided by Google™ Books (Brants and Franz, 2006). We also performed a search for "Wolong Nature Reserve" in all international news articles published in the English language since 1980 using the LexisNexis® Academic search engine. The frequency of the phrase "Wolong Nature Reserve" in English books has increased since 1980, especially after 2000 (Figure 17.7A). We found a total of 806 articles using the term "Wolong Nature Reserve" published since 1980 in international news media published in the English language. The number of articles published each year remained under 11 between 1980 and 1998 and then increased to 51 during a three-year period from 1999 to 2001 (Figure 17.7B). The numbers of articles fluctuated between 20 and 60 in each of the remaining years, except for a sharp peak in 2008 (213 articles; Figure 17.7B) due to the devastating earthquake.

### Causes

A number of factors have led to the flows of information from Wolong to distant systems. Because of greater emphasis on sustainability worldwide, many global citizens are concerned about endangered and charismatic species like the giant panda, which results in a large amount of research about pandas in Wolong. What is more, as an emblem of China, the panda's important role in diplomacy has also attracted the media and scientists' attention. Being home to the panda as a global conservation icon, Wolong is an important place for

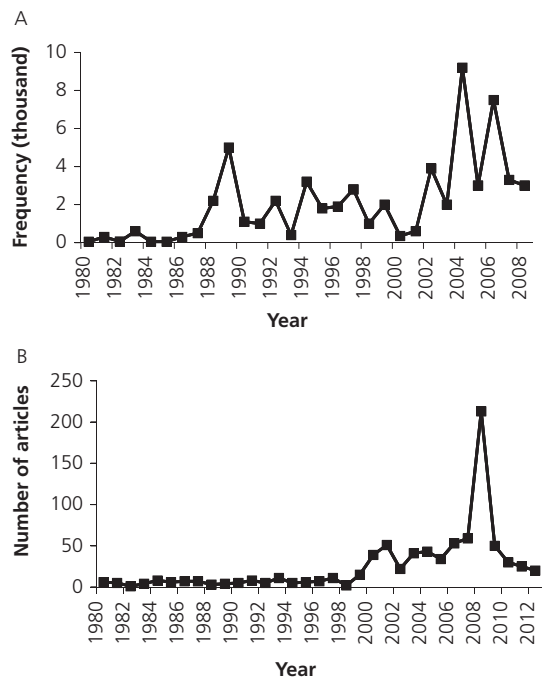


**Figure 17.7** (A) Temporal changes in the frequency of "Wolong Nature Reserve" in published English books (unsmoothed) between 1980 and 2008; (B) number of international news articles containing the words "Wolong Nature Reserve" published in the English language from 1980 to 2012, as documented using the LexisNexis® Academic search engine. Adapted from Liu et al. (2015a).

panda conservation. As a flagship national nature reserve, it has received exceptional national and international financial and technical assistance (Liu et al., 2001). Although there are 67 nature reserves for panda conservation (State Council Information Office of China, 2015, Liu, 2015), Wolong is one of the first and one of the largest. Tourism is another mechanism that has helped spread information about Wolong. In addition, Wolong hosts a number of captive pandas in the breeding center and sends many of these pandas to places around the world (through the panda loan program described in Section 17.2.1). A number of events collectively led to the initial increase in media attention in the 1999–2001 period. These included a boom in captive panda breeding (Mouland, 2001), the arrival of the second pair of Wolong's pandas at the National Zoo in Washington DC (Pan, 2000), and the publication of a paper documenting the rapid decline of panda habitat in Wolong despite its protected status (Liu et al., 2001). The reason for the rapid increase in publications in 2008 stems from the Wenchuan earthquake (see example research articles on the earthquake impacts by Viña et al. (2011), Yang et al. (2013a), and Yang et al. (2015)).

**Effects**

The effects of information flows out of Wolong are numerous. Information shared about Wolong helps raise awareness among the general public regarding the plight of the endangered giant panda, as well as broader conservation issues in China and those facing other wildlife species around the world. Furthermore, scientific research related to giant panda conservation can inform decision-making surrounding conservation of other endangered species, not only in Wolong but also across the globe (Liu et al., 2003, Schaller, 1994). In Wolong, visits from journalists promote the local economy. Also, some researchers like us pay local field workers to assist with data collection and analysis.

Feedbacks also can occur because the information disseminated from Wolong helps attract tourists to visit Wolong from receiving systems, who engage in various activities that affect the sending system. Another feedback occurred when people around the world who had heard about or visited Wolong sent donations to support disaster relief after the Wenchuan earthquake (Liu, 2012). Also, the Chinese government referred to results from scientific research in Wolong (Liu et al., 2001) for more effective panda conservation.

### 17.2.4 Conservation subsidies

Wolong has received substantial external financial support from the Chinese government and the international community since its establishment as a nature reserve in 1963. Wolong is a national-level nature reserve and overseen by both the central government's State Forestry Administration in Beijing and the Forestry Department of Sichuan Province in Chengdu. Therefore, financial support from the governments is supplied regularly. For instance, a major road construction project was initiated in 1992 financed by a 35 million yuan investment from the central government (Liu, 2012). The goal of this project was to link Wolong to neighboring rural communities and outside markets. International organizations such as the World Wildlife Fund (WWF) have also invested in Wolong since the 1980s. Since the earthquake, the Hong Kong special administrative region government has committed a total of HK$1.58 billion (US$204 million as of May 2012) investment for earthquake reconstruction efforts in Wolong (*News.Gov.Hk*, 2014).

Conservation subsidies have also been provided to local residents in Wolong to compensate them for participation in conservation efforts. These include the Grain to Green Program (GTGP, since 2000) and the Natural Forest Conservation Program (NFCP, since 2001) (Liu et al., 2008). GTGP provides subsidies to farmers to convert their cropland on steep slopes to forests (see Chapter 13). In Wolong, NFCP offers subsidies for local households to monitor the forests to prevent illegal harvesting. In this section, we focus on the subsidies from NFCP and GTGP.

**Telecoupled systems**

Wolong is the receiving system for conservation subsidies while the rest of China (represented by the Chinese government) is the sending system. The rest of the world is the spillover system, as ecosystem services (e.g., carbon sequestration by forests) provided by Wolong can abate global climate change.

### Agents

Government officials in China and farmers in Wolong are the agents who provide and receive financial support, respectively. Agents in the spillover system include the general public affected by ecosystem services provided by the programs.

### Flows

The main flows for external financial support are monetary funds. The cumulative amount of NFCP payments between 2001 and 2007 was almost 18 million yuan (ranging from 2.2 to 2.6 million yuan per year). The cumulative amount of GTGP payments between 2000 and 2007 was over 10 million yuan (ranging from 0.96 to 1.32 million yuan per year; Figure 17.8).

### Causes

The implementation of GTGP and NFCP in Wolong was due to both national and local factors. At the national level, the huge floods in 1998 prompted the establishment of these two conservation programs in order to improve soil water retention and prevent erosion (Liu et al., 2008). At the local level, the degradation of forests and panda habitat in Wolong caused the local government to seek ways to minimize the continuing destruction of forests and panda habitat. There were also economic causes. At the national level, the government recognized the need to improve the livelihoods of the millions of rural poor. At the local level, the administration recognized the need to provide alternative forms of income for residents living inside Wolong, who were economically limited by related conservation initiatives (e.g., the ban on timber harvesting).

### Effects

In the receiving system, external financial support has had many positive effects. The majority of local residents identified positive effects from NFCP, such as economic gains and environmental benefits (e.g., reducing soil erosion and landslides; Yang et al., 2013c). For example, the subsidies from NFCP and GTGP respectively accounted for 5% and 8% of the average household income as of 2005 (Liu et al., 2013b). On the other hand, NFCP restricts forest use by locals. After NFCP started, electricity consumption in the reserve doubled, and the labor spent on fuelwood collection decreased by nearly half between 1998 and 2001 (Yang et al., 2013c). These programs also have helped forest and panda habitat recovery (Viña et al., 2011). Forest cover in Wolong decreased from 106 000 ha in 1965 to 70 000 ha in 2001 but recovered to 79 000 ha by 2007 through the implementation of these programs (Yang et al., 2013c). However, the negative effects of GTGP on

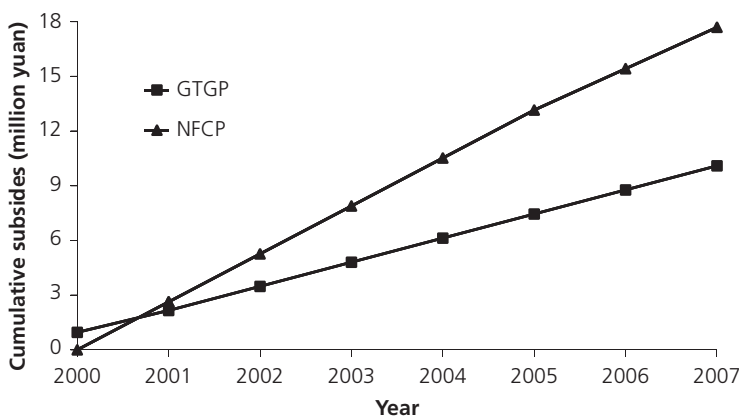


**Figure 17.8** Cumulative amounts of subsidies to Wolong from the Chinese central government through the Natural Forest Conservation Program (NFCP) and Grain to Green Program (GTGP). Data are from government records on investment in NFCP and GTGP (Wolong Nature Reserve, 1998–2010, Wolong Nature Reserve, 2005). NFCP and GTGP payment rates are flat (i.e., the present values in each corresponding year are not discounted). Adapted from Liu et al. (2015a).

household income might outweigh its positive effects. The compensation level (3150 yuan per ha per year) might be too low to cover the potential income loss due to the lost cropland. Based on a household survey in 2006, 1 ha of cropland planted with off-seasonal cabbage (a cash crop) could bring as much as 15 times more income than the subsidies provided by GTGP (Liu et al., 2013b).

Feedbacks also occur. NFCP and GTGP have led to increases in forest cover, which enhances the capacity of carbon sequestration and climate change mitigation. More forest cover may also attract more tourists (Liu et al., 2012). The recovery of forests also improved habitat for many wildlife species, including crop-raiding species such as wild pigs. Increased crop raiding may motivate farmers to convert more farmland to forest land to reduce future crop losses and to find jobs in cities.

### 17.2.5 Trade of agricultural products

Agriculture has been the central livelihood strategy in Wolong for centuries (Ghimire, 1997). Households grow subsistence crops for direct household consumption and cash crops to sell to outside markets. Some of the main cash crops include cabbages, carrots, corn, and potatoes. Wolong residents also engage in livestock production, including raising yak, goats, sheep, cattle, pigs, and horses for both subsistence and selling meat to outside markets.

#### Telecoupled systems

Wolong is the sending system for trade of agricultural products as Wolong farmers sell products. The receiving systems are diverse, including the cities of Chengdu and Dujiangyan, which are 130 and 50 kilometers from Wolong, respectively. The spillover systems include other rural areas around China that are affected by the trade of agricultural products between Wolong and the receiving systems.

#### Agents

The agents in the trade of agricultural products include farmers in Wolong, traders, and consumers of agricultural products. Around 80% (306 of 381 laborers from 180 surveyed households) of Wolong laborers were involved in cash crop production in 2007 (Yang et al., 2013b). Agents in the spillover systems include agricultural sellers and buyers affected by changes in the market as a result of Wolong's trade activities.

#### Flows

Flows include food products transported out of Wolong and the money coming into Wolong. The total income earned from cabbages and livestock has been generally increasing from around 4.5 million yuan in 1998 to nearly 9.8 million yuan in 2007, or 11.7 million in 2007 after taking into account China's consumer price index increase of 19.6% during this period and standardizing to 1998 rates (Sichuan Provincial Bureau of Statistics, 2007; Figure 17.9A). However, the percentage of households with these income sources declined from over 90% to just over 60% during the same period (Figure 17.9B).

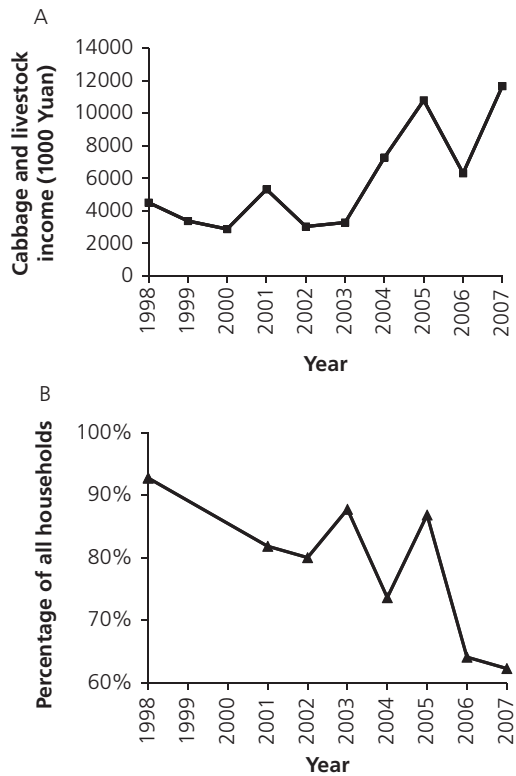


**Figure 17.9** (A) Total income from cash crops and livestock in Wolong (× 1000 yuan), discounted to 1998 rates using consumer price index statistics from Sichuan Provincial Bureau of Statistics (2007); (B) percentage of sampled households with income from both cash crops and livestock. Adapted from Liu et al. (2015a).

**Causes**

There is a cultural cause stemming from the long history of agriculture in the reserve and the traditions passed down in family lineages. One of the other main causes of agricultural trade is economic. An important source of income for Wolong residents has come from producing agricultural products for outside markets. The increase in agricultural production in Wolong is in part attributed to the construction of the road that provides reliable access to outside markets. However, destruction of the road during and after the 2008 earthquake has severely impacted cash crop production in Wolong because farmers no longer have reliable means to transport their crops.

**Effects**

The trade of agricultural products has helped farmers in Wolong earn cash and improve their economic conditions. For example, in 2007, Wolong farmers in 159 surveyed households earned 1.34 million yuan from selling cabbages, potatoes, and livestock (Liu et al., 2013b). At the same time, those agricultural products helped meet the demands of people in cities. In the trade of agricultural products, money from selling the products is a strong feedback. Some of the income generated from the trade of agricultural products allows for the purchase of agricultural technology (e.g., industrial products) which can help produce more agricultural products.

### 17.2.6 Trade of industrial products

Demand for industrial products manufactured outside Wolong has also substantially increased over time. For example, in recent years, local people have invested more on agricultural inputs to improve crop production. This investment includes chemical fertilizers, e.g., carbamide, phosphate, and potash (Wolong Administration Bureau Department of Social and Economic Development, 2008). Also included is plastic film purchased to cover soils to decrease weeds, maintain temperature, and increase water retention.

**Telecoupled systems**

Wolong is the receiving system for industrial products. There are many sending systems, including the same cities that are the receiving systems for agricultural products. Other sending systems are technology hubs in cities farther away, such as Beijing, Shanghai, and even as far away as some in the USA. Spillover systems include areas under environmental impacts from technology production and application. For instance, fertilizers applied in Wolong may leach into the Pitiao River, which feeds into the 735-km Minjiang River stretching across Sichuan Province.

**Agents**

Agents include manufacturers and suppliers of industrial products such as fertilizers and plastic films that Wolong farmers purchase. Two of China's leading fertilizer production companies with plants in nearby cities include Sichuan Chemicals and Sichuan Meifeng Chemical, companies that are part of a greater network of China's industrial sector. Agents in spillover systems include farmers and the general public who are affected by accumulation of chemical fertilizers, as well as agricultural traders competing with Wolong farmers on the market.

**Flows**

Flows include money going out of Wolong and industrial products coming into Wolong. The total amount of fertilizers purchased increased from a little over 300 tons to 440 tons per year between 1998 and 2007 (Figure 17.10A). Just as the percentages of households with incomes from agricultural products declined, the percentages of households that purchased fertilizers each year also declined over time from more than 90% to just above 60% (Figure 17.10B). The total amount of plastic film purchased per year for the entire reserve also decreased over time from nearly 13 000 kg to 5000 kg, with some fluctuations (Figure 17.10C).

**Causes**

Many of the aforementioned causes of increased trade of agricultural products also apply to trade of industrial products. To increase agricultural production, large amounts of fertilizers and plastic films were needed. One other important cause of imported agricultural technology is that technology can improve the efficiency of land use and produce more agricultural products per unit of land. Such efficiency can help people earn more money and

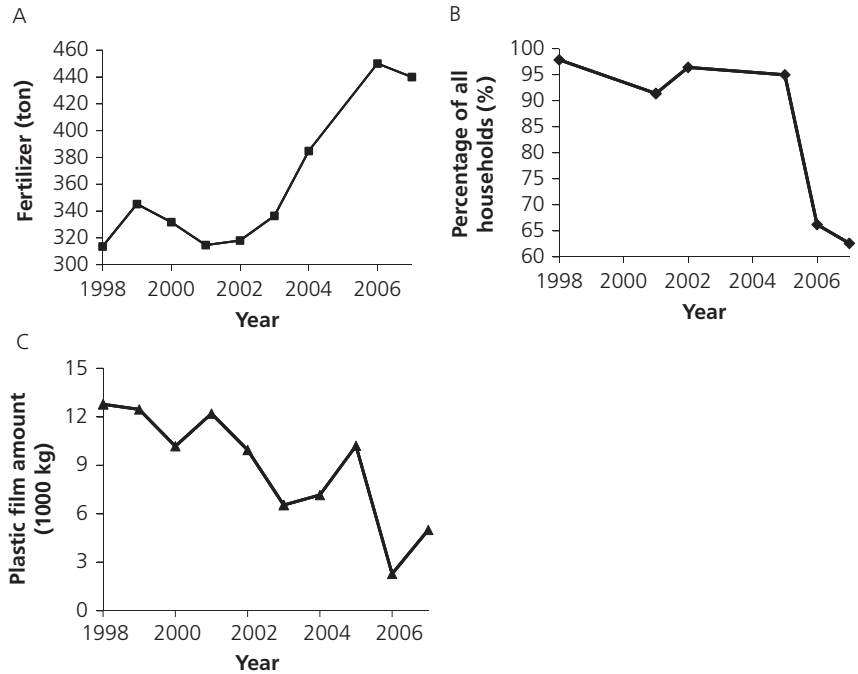


**Figure 17.10** (A) Total amount of fertilizers purchased by Wolong farmers from outside markets over time; (B) percentage of sampled households purchasing fertilizers over time; (C) total amount of plastic film purchased by Wolong farmers over time. Adapted from Liu et al. (2015a).

mitigate the contraction of the area used as cropland due to reconversion to forest.

**Effects**

Using fertilizers made in cities has increased agricultural production but also polluted the local environment (e.g., soil and water) and affected organisms. In 2007, Wolong farmers in 177 surveyed households spent 114 000 yuan on fertilizers (Liu et al., 2013b). The effects of fertilizers extend to spillover systems. For instance, nitrogenous fertilizer production in China is known for having a large impact on GHGs. Chinese companies mainly use coal as an energy source to produce nitrogenous fertilizers, while the rest of the world mainly uses natural gas (Kahrl et al., 2010). GHGs emitted from fertilizer production impact distant systems all over the world via contributions to climate change. For example, the 440 tons of fertilizer applied in Wolong in 2007 (see Figure 17.10A) could emit as much as 4092 tons of $CO_2$ (9.3 $tCO_2$ $tN^{-1}$, including the fertilizer production process; Kahrl et al., 2010).

A positive feedback drives this telecoupling. The use of industrial products helps increase agricultural yield, thus generating more income that could be used to purchase more industrial products including agricultural technology.

## 17.3 Similarities, differences, and relationships among telecouplings

Among the telecoupling processes analyzed above, all but one increased in strength over time until 2008 when the Wenchuan earthquake occurred (Figure 17.11). The telecoupling process with the most pronounced change is the information spread about Wolong (occurrence of words "Wolong Nature Reserve" in published English books and articles). The only telecoupling that has decreased somewhat is the purchase of plastic film from outside. This change is most likely attributed to the decrease in cropland area due to the implementation of NFCP and GTGP. All telecouplings except NFCP and GTGP occurred in or before 1998. The

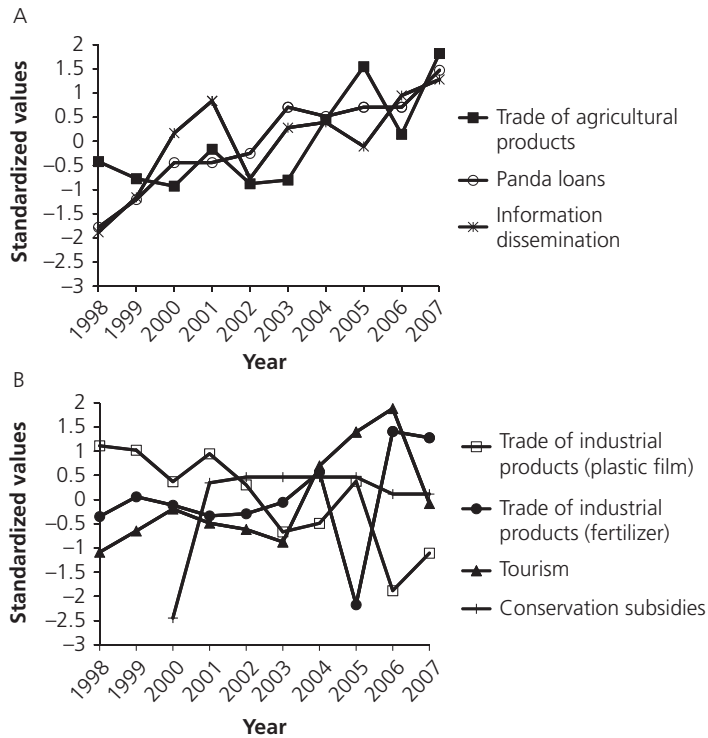


**Figure 17.11** Changes in telecouplings for those with flows (A) leaving and (B) entering Wolong Nature Reserve from 1998 to 2007. Values shown are standardized across years. Trade in agricultural products refers to total income from cash crops and livestock in Wolong. Panda loans are the number of pandas sent from Wolong to outside zoos on loan. Information dissemination is the number of international news articles containing the words "Wolong Nature Reserve" published in the English language. Trade of industrial products is presented in two parts: total amount of fertilizers and total amount of plastic film purchased by Wolong residents. Tourism is represented by the total number of incoming tourists visiting Wolong. Conservation subsidies are total amounts of funding that Wolong received for the Natural Forest Conservation Program (NFCP) and the Grain to Green Program (GTGP). Adapted from Liu et al. (2015a).

implementation of GTGP and NFCP began in 2000 and 2001, respectively (Figure 17.11).

The relationships among the telecouplings are complex. They may enhance each other. Information spread may be a key driver for many other telecouplings, since it increased to a greater degree and occurred earlier than other telecouplings (Figure 17.11). For instance, information spread through media exposure has historically been a key driver of the increase in tourism to Wolong (Liu, 2012). During the early years of tourism development in Wolong, there was a spike in tourists' arrival in 1983 (from less than 10 000 to over 20 000 visitors). This sudden increase was triggered by one of the first international media reports on Wolong regarding a suspected panda starvation resulting from a mass bamboo flowering and die-off (Liu, 2012). Since then, the Chinese government has designated Wolong as a tourist attraction, invested in tourism facilities and promoted it through the global news media. Thus, the government has increased the exposure of Wolong to the rest of the world. For instance, 24% ($n$ = 70) of the visitors to the Wolong breeding center whom we interviewed in 2005 said they had previously read print media reports on Wolong, and 29% had seen television programs (Liu, 2012). In addition, increased investment in tourism and increases in tourist volumes have in turn increased media exposure about Wolong. For instance, a Google search for "Wolong"

and "tour" in English yielded over 80 000 hits as of September 2014, many of which were promotional tourist packages and tourist recommendations.

Panda loans have significantly affected the international information spread about Wolong. Around 20% of all media reports found in LexisNexis® about Wolong concern panda loans, which is more than any other topic. Such loans allow people from around the world who do not have the opportunity to visit Wolong to still learn about Wolong. Loaned pandas often require multimillion dollar investments in exhibits, many of which incorporate educational materials to share information about Wolong with visitors. Loaned pandas are also featured on webcams that are geared toward disseminating information to a wide audience. For instance, more than 237 000 hits were recorded on the panda cam website of the National Zoo in Washington DC within one day after the birth of a baby panda (*Associated Press*, 2012). This website thus serves as an information portal for Internet users worldwide. Information spread may also encourage donations to Wolong's breeding center. In recent years, such funds have helped pay for the operating costs of a giant panda reintroduction program geared toward releasing pandas to the wild (Pandas International, 2012).

Another example is conservation subsidies and tourism. When interviewed, local people in Wolong perceived a potential benefit from NFCP for tourism development, presumably due to their perception that protecting the forest would help attract nature-based tourists (Yang et al., 2013c). Another related conservation program called the Grain to Bamboo Program (GTBP) has an even greater link to tourism. The GTBP pays local people to plant bamboo mainly along the roadways, in part to improve the roadside aesthetic appeal of the reserve to visiting tourists (Yang et al., 2013c).

Telecouplings may also offset each other. The trade of agricultural and industrial products is at odds with off-farm income-generation activities. For example, the decrease in the amount of plastic film used may in part be due to an over 50% reduction in an average household's agricultural land as a result of GTGP. Tourism also provides a source of non-farm income that may discourage agricultural development, and in turn, agricultural trade. For example, households with tourist-related income had on average 50% less farmland compared to households not engaged in tourism in 2006 (average of 0.63 vs 1.25 mu, 1 mu = 0.0667 ha; Liu et al., 2012). Households with more initial cropland are also significantly less likely to take up tourism as an alternative income source (Yang, 2013). Off-farm telecouplings also affect each other. For instance, tourism had a significant positive effect on total household income, but the effect of tourism was also significantly dependent upon the household's participation in NFCP (Yang, 2013; see also Chapter 9). Tourism and NFCP participation were antagonistic in affecting total household income because those with lower tourism income only had higher total income if their income from NFCP was also high (Yang, 2013). Although tourism provides a potentially higher economic gain for locals who participate, it is less stable compared to agriculture, NFCP, and GTGP. The instability leaves many locals wary about investing in tourism activities (e.g., see fluctuations in Figure 17.6A; Yang, 2013).

There are spatial overlaps between some telecoupling processes. Perhaps this is best illustrated via the relationship between panda loans and tourists (e.g., destinations of panda loans and origins of tourists, Figures 17.3–17.5). After excluding the tourists coming from within Sichuan and the nearby Chongqing municipality, there is a significant positive correlation between panda loan destinations and origins of tourists across China ($R = 0.72$, $p < 0.05$). Three of the top four locations are shared between panda loans and tourists (Beijing, Guangzhou, and Shanghai). Internationally, the top two countries for both panda loans and tourists are also shared: Japan and the USA. These similarities reflect the locations with high human populations in developed areas that would be interested and have resources to undertake both international travel and hosting pandas in zoos. Loans began to increase several years prior to the boom in tourism (Figure 17.11), largely due to the rapid increase in breeding technologies that preceded tourism development. Loans may have encouraged subsequent tourism by raising the international status of Wolong.

Telecouplings may also lead to the formation of other telecouplings. The panda loans are a good example because they induce and are induced by other telecouplings such as trade agreements between China and other

countries, including procurement of cars, renewable energy, and other resources by China (Buckingham et al., 2013). For instance, the loan of pandas to the Edinburgh Zoo in 2011 was part of a £2.6 bn (US$3.94 billion) collection of business deals, including China securing rights to oil from a Scottish oil refinery (*The Guardian*, 2011).

## 17.4 Discussion

This chapter represents the first effort to study multiple telecouplings across borders and across local to global scales. It uncovers many similar and different spatiotemporal patterns and relationships among multiple telecouplings. The distance-defying patterns illustrated by tourism and panda loans suggest that geographical proximity is not necessarily the only determinant of telecouplings. For example, tourist destination choices are mainly determined by distance and cost, but this process is also heavily shaped by tourist motivations such as discovering new places and experiencing other cultures (Fesenmaier et al., 2006, Nicolau and Mas, 2006).

Telecouplings illustrated in this study are quite common around the world. Some telecouplings may be independent of scale and context, behaving in a similar manner across systems at different scales and in different contexts. For example, almost all rural areas import industrial products such as fertilizers produced elsewhere. On the other hand, many farmers sell agricultural products to outside markets (Jacoby, 2000). Many rural areas are destinations for tourists who live in cities (Lane, 1994). Information about various places is disseminated worldwide through publications, mass media, the Internet, and other communication channels. Financial support from external sources for conservation (e.g., payments for ecosystem services) is increasingly common worldwide (Chen et al., 2009, Yang et al., 2013c). Pandas are endemic to China and panda loans are relatively limited at the global scale. But many countries or places offer other wildlife species such as tigers, zebras, alligators, lions, and wolves to numerous zoos (Braverman, 2010). In many ways, the presence of other wildlife species in zoos plays roles (e.g., education) similar to the role of loaned pandas.

It is much more challenging to study telecouplings than local couplings (human–nature interactions within a system) because telecouplings involve many components that go beyond a single location, across multiple scales, and across administrative boundaries. Naturally it is even more challenging to study and quantify multiple telecouplings simultaneously than one telecoupling at a time. As a result, many research gaps exist. The biggest unknown ones are the spillover systems. In some cases, it is even unclear where the spillover systems are. Furthermore, many other environmental and socioeconomic effects across the telecoupled systems are not measured quantitatively. Feedbacks and relationships among multiple telecouplings require further quantification. While much remains to be done, this study lays a good foundation for future research and management to enhance positive effects and reduce negative effects of telecouplings on environmental sustainability and human well-being.

## 17.5 Summary

Many studies have focused on human–nature interactions within a particular area. There is little research on multiple reciprocal interactions, simultaneous socioeconomic and environmental impacts, and relationships with other areas. This chapter addressed these important knowledge gaps by applying the new integrated framework of telecoupling (socioeconomic and environmental interactions among two or more areas over distances). Results show that even the small and remote model coupled system of Wolong Nature Reserve had multiple telecoupling processes with the rest of the world. These included panda loans, tourism, information dissemination, conservation subsidies, and trade of agricultural and industrial products. The telecoupling processes exhibited non-linear patterns and have varying socioeconomic and environmental effects in various areas across the world. For example, as of 2010, 85 pandas had been loaned from Wolong to zoos in several countries. These loans have diverse effects such as introducing considerable economic costs to the receiving zoos and creating diffuse $CO_2$ emissions via animal transport. The chapter explored the substantial similarities, differences, and

relationships among different telecouplings, which cannot be detected by traditional separate studies. For instance, most of the telecouplings examined have been increasing over time. Telecouplings may also offset one another. Tourism was at odds with agricultural production and trade. Households in Wolong that participated in tourism had on average 50% less farmland compared to households not engaged in tourism in 2006. Such an integrated study leads to a more comprehensive understanding of distant human–nature interactions and has important implications for global sustainability and human well-being.

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