ASIA & THE PACIFIC POLICY STUDIES
Australian National University
Australian Government Department of Foreign Affairs and Trade

Asia & the Pacific Policy Studies, vol. 1, no. 1, pp. 230–250
doi: 10.1002/app5.17

Original Article

Forest Sustainability in China and Implications for a Telecoupled World

Jianguo Liu*

Abstract

China's forest cover has been increasing in the past three decades, which is in sharp contrast to rapid declines in other natural resources. Understanding the mechanisms of forest recovery and their effects is essential for sustaining forests in China and elsewhere. Some studies suggest that imports of forest products have contributed to the increase in forest cover of China and the decline in forest cover of exporting countries. However, it is not clear whether other countries beyond the exporting countries are affected. Using the framework of telecoupling (socioeconomic and environmental interactions over distances), we found that China's forest cover increase is affected by multiple telecoupling processes (e.g. trade of food and forest products) and their interactions with each other and with other factors. The socioeconomic and environmental impacts of telecoupling processes go well beyond China and the exporting countries. As China's demand for forest products and other ecosystem services such as food and water continues to rise, telecouplings will become even more important for sustainable forests, food security, water security, human well-being and environmental sustainability in the future. New and more effective policies are needed to minimise negative and enhance positive impacts of telecouplings on China and other countries around the world.

Key words: sustainability, telecoupling, trade, investment, food

1. Introduction

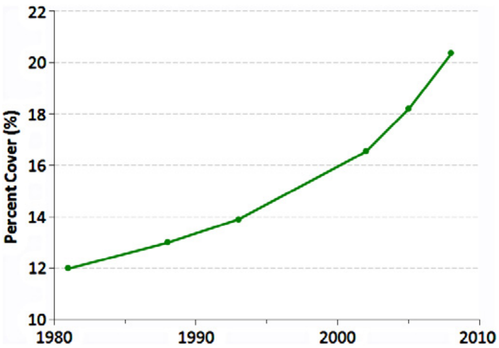
Sustainable development has been a major challenge around the world (World Commission on Environment and Development 1987). The fate of China, the world's most populous country and second largest economy, shapes global sustainability enormously (Liu 2010). In the past three decades since China's open-door policy, China's economy has grown with approximately 10 per cent a year on average. However, China's environment has been degrading (Liu & Raven 2010).

In China, all major natural resources (e.g. water, grassland) except one have declined over time (Liu & Raven 2010). This only exception is forest cover. Since the early 1980s, China's forest cover has increased (Figure 1). China is among a small group of countries (e.g. United States, Italy, Norway, Spain, Switzerland) whose forest coverage has been increasing or is in transition (from net

* Center for Systems Integration and Sustainability, Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48823-5243, USA; email <liuji@msu.edu>. Sincere thanks go to Tom Kompas for the invitation to write this article; Joanna Brodrick, Shuxin Li and Sue Nichols for very helpful assistance; anonymous reviewers for constructive comments; and the National Science Foundation, the National Aeronautics and Space Administration, Michigan AgBioResearch, and Michigan State University for financial support.

© 2013 The Author. *Asia and the Pacific Policy Studies* published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University. This is an open access article under the terms of the Creative Commons Attribution-NonCommercial License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

Figure 1 Dynamics of Forest Cover in China (Liu & Diamond 2005; China Statistical Yearbooks; http://politics.people.com.cn/GB/1026/10397213.html, in Chinese)



forest area loss to net forest area gain) (Mather 1992; Rudel 1998). While there are a number of factors behind forest transition (Rudel 2005; Meyfroidt & Lambin 2011), some studies suggest that imports of forest products from other countries have contributed to China's increase in forest cover, while forests in the exporting countries have suffered from such imports (Zhu et al. 2004; Lang & Chan 2006; Rudel et al. 2009; DeFries et al. 2010; Lambin & Meyfroidt 2011).

However, there is a lack of systematic analysis of China's forest sustainability, and many questions are not answered or even asked. For example, how do imports of forest products interact with other factors in affecting China's increase in forest cover? Are there other countries affected besides those that supply forest products to China? In this article, we address these and other related important questions under a new integrated framework. Specifically, we first provide an overview of the framework. Then, we apply the framework to address a series of issues related to China's forest sustainability. Finally, we discuss how China may continue to achieve forest sustainability while exerting minimal negative and maximum positive impacts globally.

2. Overview of the Telecoupling Framework

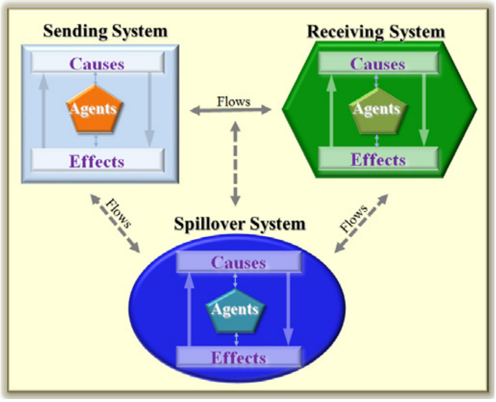
From the perspective of systems theory (Bertalanffy 1969), almost all systems are open ones, which interact with outside systems through exchanges of information, material and energy. Some of the outside systems are nearby, while others are far away. Many disciplines consider interactions between distant systems or systems that are far away. For example, in atmospheric science, the concept of teleconnections is used to describe environmental interactions between climatic systems over distances (which may be thousands of miles apart) (Glantz et al. 1991). In economics, globalisation (Levitt 1982) refers to socioeconomic interactions between distant human systems (e.g. on the continents of Asia and North America). In demography, the concept of migration refers to distant movement of people (e.g. from China to the United States); while in ecology it refers to distant movement of animals, such as locusts (*Locusta migratoria*) throughout three continents (Africa, Asia, Australia), Kirtland's warbler (*Setophaga kirtlandii*) between the Bahamas and Michigan of the United States) and Pacific Salmon between the oceans and the upper riches of rivers.

While research on distant socioeconomic or environmental interactions separately has generated useful insights, other aspects of interactions are ignored although all interactions actually are related. For example, when locusts migrate from one place to another, they can eat almost all crops and thus cause severe economic losses. When goods and products are traded among countries, they also generate environmental impacts (e.g. carbon dioxide (CO_2) emissions during transport). Thus, understanding socioeconomic and environmental sustainability requires the integration of socioeconomic and environmental interactions across multiple coupled human and natural systems over distances (NSF Advisory Committee for Environmental Research and Education 2009).

Coupled human and natural systems are integrated systems in which humans and natural systems interact (Liu et al. 2007a, 2007b). They can be at different scales (e.g. local to global). At the national level, each country, such as China, is a coupled human and natural system. Socioeconomic and

© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

Figure 2 Telecoupling Framework (Adapted from Liu et al. 2013a)



environmental interactions at the local level may be referred to as local couplings. Socioeconomic and environmental interactions between multiple coupled human and natural systems over distances are termed 'telecoupling' (Liu & Yang 2013; Liu et al. 2013a). In other words, the concept of telecoupling is a logical extension of the concept of 'coupling' ('tele' means distant). Just as 'ecosystem services' encompasses different types of services (e.g. provisioning, supporting, regulating and cultural), telecoupling encompasses multiple types of distant interactions. For example, it expands the concept of teleconnection by including socioeconomic interactions and extends the concept of economic globalisation by including environmental interactions (Liu et al. 2013a). Furthermore, it expands previous concepts by explicitly considering feedbacks (i.e. reciprocal interactions among different coupled systems). It also expands the concept of weak ties in social sciences that refers to non-frequent and transitory social relation (Montgomery 1992) because the telecoupling framework addresses not only interactions at the same levels (or scales, e.g., weak ties between individuals), but also across levels (or scales) through various pathways.

The telecoupling framework consists of five major interrelated components: systems, agents, flows, causes and effects (Liu et al. 2013a) (Figure 2). *Systems* are coupled human and natural systems. Depending on their functions, systems can be classified as sending systems (e.g. supplying systems, origins, exporting countries), receiving systems (e.g. destinations, importing countries) and spillover systems (Figure 2). Sending systems provide material/energy and information for flows, while receiving systems obtain information and material/energy from the sending systems. Spillover systems are a byproduct of connections between sending and receiving systems. They may be connected to sending and receiving systems in various ways (Liu et al. 2013a): as an intermediate stopover between the two systems (e.g. airport layover or a migratory bird stopover), as the pathway between the sending and receiving systems (e.g. channels for transport), or as an outside entity that is connected with sending and receiving systems (e.g. a third party in trade negotiations) (Liu et al. 2013a).

Flows refer to exchanges of material/energy or information between the systems. Material/energy comprises biophysical and socioeconomic entities (e.g. goods, food, natural resources, organisms, carbon), and information contains knowledge and agreements (e.g. trade agreements).

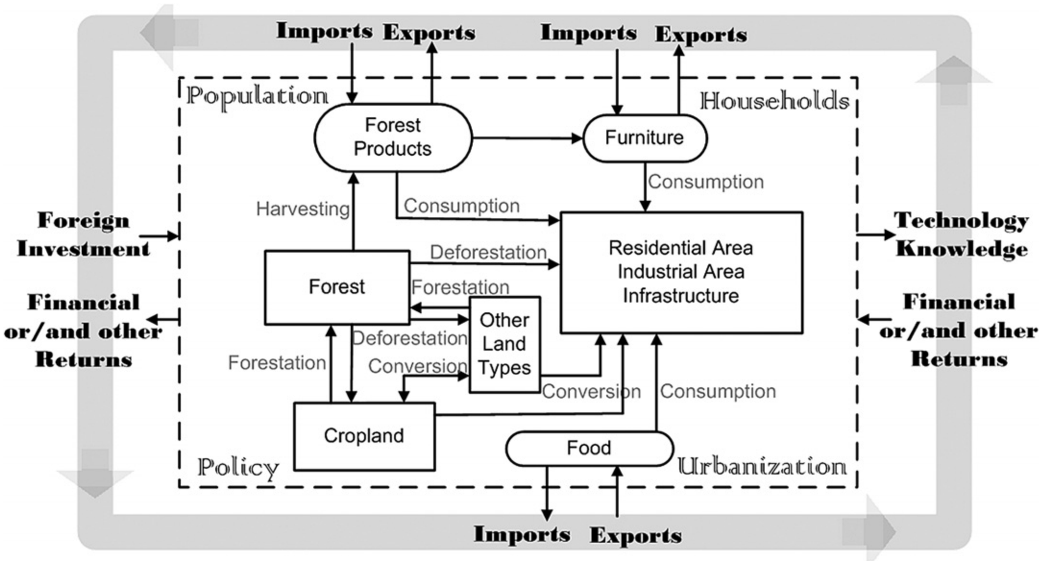
Agents promote or hinder the flows of material/energy or information among the systems. They include autonomous decision-making entities within sending, receiving and/or spillover systems that are directly or indirectly involved in telecouplings, such as via the formation or dissolution of flows. They can be individuals or groups of humans or animals (e.g. households, institutions, herd of animals).

Causes produce a telecoupling between a minimum of two coupled human and natural systems, which lead to effects on one or more of the systems. The causes are factors that generate dynamics (e.g. emergence, changes in strength) of a telecoupling. Most telecouplings have multiple causes (e.g. economic, political, technological, cultural and ecological) that are originated from a sending, receiving and/or spillover system.

Effects are environmental and socioeconomic consequences or impacts of a telecoupling. They can appear in sending, receiving and/or spillover systems. Types of effects in individual

© 2013 The Author. *Asia and the Pacific Policy Studies* published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

Figure 3 Conceptual Model of Factors Affecting Forest Cover Dynamics



coupled systems (Liu et al. 2007b) may also occur in telecoupled systems, such as feedbacks and non-linearity. Effects may have time lags (not emerging until years or even decades after the initiation of a telecoupling) and legacy (not disappearing until many years to decades after the emergence of a telecoupling).

Telecouplings at different scales may have interrelationships with each other and with local couplings (i.e. cross-scale interactions). Based on geographical/organizational scales, telecouplings may be classified as global, continental, national and regional telecouplings, which are across the globe (between continents), across a continent (between nations within the continent), across a nation (between regions of a nation), and across a region (within a nation), respectively. (Sometimes, a region may refer to a world region such as a continent, and in this case a region within a nation can be referred to as a subnation.) Different types of telecouplings also may have interrelations with each other.

3. Application of the Telecoupling Framework to China's Forest Sustainability

In this section, we apply the telecoupling framework to China's forest sustainability. As shown in Figure 3, dynamics of forest cover are affected by multiple interactive factors. Afforestation and reforestation increase forest cover by converting other types of land (e.g. cropland), while deforestation reduces forest cover by converting forests to other land cover types. Natural factors such as natural succession and natural disturbances (e.g. fires and landslides) also change forest cover. In this article, we focus on human factors that affect forest cover.

Deforestation can generate forest products (e.g. timber) and convert forestland into cropland, residential areas or industrial areas, infrastructure (e.g. roads) and other types of land (Figure 3). It has contributed to China's dramatic land transformation (Liu et al. 2005; Liu & Tian 2010). Conversion into residential areas also requires timber for housing construction and wood for furnishings. On the other hand, afforestation and reforestation have taken place in cropland, previously harvested forest area (Bearer et al. 2008; Chen et al. 2010) and other types of land such as barren land (Liu et al. 2008).

Deforestation and forestation are in turn driven by a series of factors such as population, households, urbanisation and policy (Figure 3). In the past half century, China's population has more than doubled—reaching 1.35 billion in 2012 (National Bureau of Statistics of China

© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

2013). The number of households in China has been growing even faster—nearly three times as fast as its population from 1985 to 2000 alone—because the average number of people in a household declined from 4.5 to 3.5 (Liu & Diamond 2005). As resource use efficiency per person in smaller households is lower than in larger ones (Liu et al. 2003), China's fast decline in household size and rise in household number have had enormous impacts on forests (e.g. more use of fuelwood and floor space which in turn needs more timber and wood for construction and furnishings (Liu et al. 2001; Linderman et al. 2005). On average, household size in urban areas is smaller than in rural areas. As China has been rapidly urbanising (the percentage of its urban population has increased from merely 13 per cent in 1952 to 51.2 per cent in 2011), the impacts of urbanisation on forests are significant (through converting much forest to built-up area and using forest products for a variety of purposes such as housing construction).

While many of China's policies have led to massive deforestation—e.g. the Great Leap Forward movement of 1958–1961 harvested 10 per cent or more of China's forests to fuel backyard furnaces for steel production (Shapiro 2001; Liu 2010)—some policies have been implemented for forestation (Lu 2004). For example, in 1981, China implemented an 'Obligatory Tree Planting' program that called for all able citizens to plant three to five trees each year (Zhang et al. 1997). In 1994, 2.5 billion trees were planted by 490 million people (Zhang et al. 1997). The Three North Shelterbelt Program was started in 1978 to increase forest area by planting trees in 13 provinces of the three north regions (North, Northeast and Northwest China) by 35 million ha (out of the total area of 406.9 million ha). It is projected to increase forest cover from 5.05 per cent in 1977 to 14.95 per cent in 2050, the program's planned end date (State Forestry Administration of China 2010). While these numbers are impressive, the tree survivorship was very low, and in many years trees were planted in exactly the same location repeatedly. Since the late 1990s, after the 1998 massive floods (Liu & Diamond 2005), China has implemented two major national conservation programs. One is the Natural Forest Conservation Program (NFCP), which was to conserve and restore natural forests through logging bans and afforestation (Liu et al. 2008). Specifically, the NFCP aimed to lower timber harvests in natural forests from 32 million m^3 in 1997 to 12 million m^3 in 2003, and to afforest 31 million ha by 2010 through artificial planting, aerial seeding and mountain closure (i.e. forbidding human activities such as grazing and fuelwood collection) (Xu et al. 2006a). The other program, the Grain to Green Program (GTGP), was to increase vegetative cover by 32 million ha by 2010, through converting 14.7 million ha of cropland to forest and grassland and afforesting barren land and prohibiting human activities in the remaining portion of the land (Liu et al. 2013b). In fact, these policies have begun to show positive effects on forest cover (Liu et al. 2008, 2013b).

Besides the internal factors highlighted above (Figure 3), many external factors outside China through distant interactions also affect forestation and deforestation in China (Figure 3). In this article, we highlight four of them (Figure 3). Imports and exports of forest products may reduce and increase domestic production of forest products, respectively. Imports of food may allow more land for forests through reforestation or afforestation, but exports of food may stimulate more land conversion into cropland for more domestic food production. Most of the foreign investment in China has been for residential, industrial and infrastructural development, which directly and indirectly reduces forests through conversion to residential and industrial areas and infrastructure (e.g. roads). A small proportion of foreign investment has been for the development of forest industries that generates forest products and promotes afforestation and reforestation. There is close relationship between foreign trade and foreign direct investment as they substitute or complement each other in seeking markets and resources (Toppinen et al. 2010). In addition, transfer of advanced knowledge and technologies can have differential impacts on forestation and deforestation, depending on the types of

© 2013 The Author. Asia and the Pacific Policy Studies
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

knowledge and technologies. For example, knowledge on improving efficiency of forest products may reduce the demand for forest products, while powerful machinery makes harvesting forests more efficient.

Under the framework of telecoupling, we reframe all distant interactions (e.g. trade, foreign investment, technology transfer, knowledge dissemination, species invasion, migration) as telecouplings to better understand them and identify knowledge gaps (e.g. hidden socioeconomic and environmental costs and untapped benefits). Below, we describe major components of telecouplings related to forest sustainability (with focus on imports and exports of forests products and food).

3.1 Systems

During the period of 1997 to 2010, China received forest products from 161 countries, including the vast majority of Asian and Pacific countries (Figure 4a). Among the sending countries, the United States offered the largest proportion (16.4 per cent, in terms of value), followed by Russia, Indonesia, Canada, Japan, Republic of Korea, Malaysia, Brazil, Germany and Chile. On the other hand, China also exported forest products to 173 countries (Figure 4b). Among the receiving countries, Japan took the lead (21.3 per cent, in terms of value), followed by the United States, Republic of Korea, the United Kingdom, India, United Arab Emirates, Australia, Canada, Thailand and Saudi Arabia. Six of those top 10 receiving countries differed from those in the top 10 sending countries. Among the shared four sending and receiving countries, the orders of importance changed. A major use of forest products is to make wooden furniture for exports and domestic consumption. In 2009, world production of furniture was about $350 billion (CSIL Center for Industrial Studies 2009). China had the highest amount of production (accounting for 20 per cent), followed by the United States (19 per cent), Italy (8 per cent) and Germany (7 per cent). China was also the largest sending country or exporter, while the United States, Germany, France, the United Kingdom and Canada were the major receiving countries or importers (CSIL Center for Industrial Studies 2009).

In 2010 alone, 168 countries provided food to China (Figure 5a), and 196 countries received food from China (Figure 5b). The United States led food imports to China (25.7 per cent, in terms of food value), followed by Brazil (15.6 per cent), Argentina (8.2 per cent), Thailand (6.9 per cent), Malaysia (6.7 per cent), Indonesia (6.2 per cent), Canada (4.0 per cent), Australia (3.6 per cent), India (3.5 per cent) and New Zealand (2.7 per cent). The top 10 countries that received food from China (in terms of value) were Japan (19.6 per cent), the United States (10.5 per cent), Republic of Korea (6.8 per cent), Indonesia (4.9 per cent), Malaysia (4.3 per cent), Vietnam (4.1 per cent), Germany (4.0 per cent), Russia (3.6 per cent), Thailand (3.5 per cent) and the Netherlands (3.1 per cent).

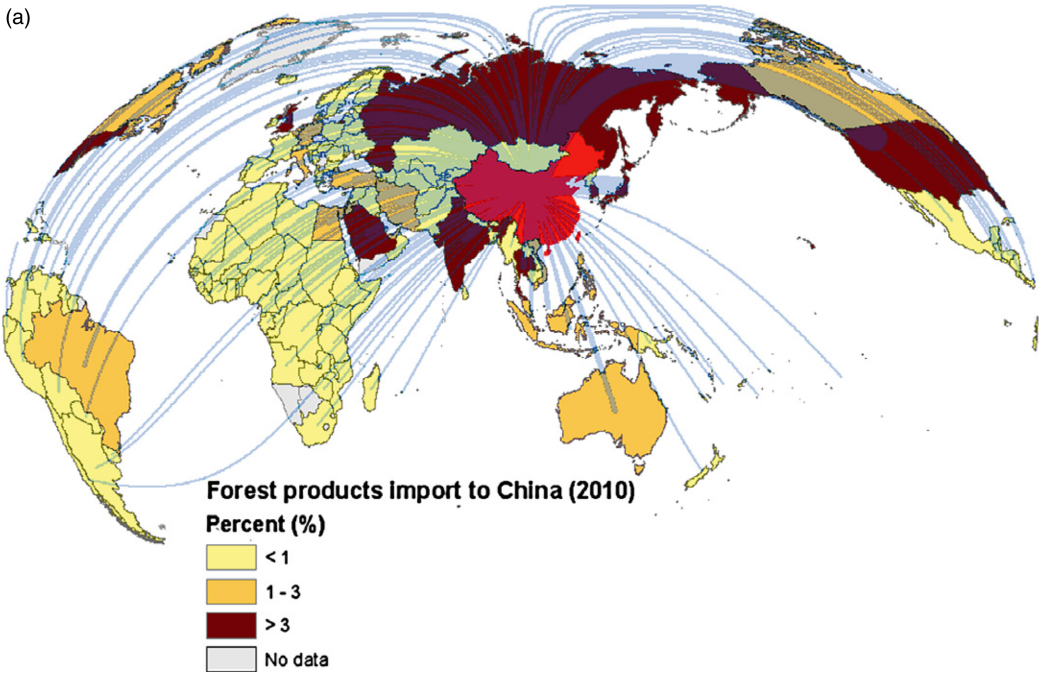
Approximately 190 countries have invested in China (The US-China Business Council 2007), such as the United States, Germany, Japan and Republic of Korea. Of which, some countries also have invested in China's forestry. They include British Virgin Islands, Canada, European Union (EU), Indonesia, Japan, Germany, Malaysia, Mauritius, Republic of Korea, Singapore and the United States (360Doc 2010). On the other hand, China has invested in more than 170 countries, especially in Africa, Asia and Europe (Ministry of Commerce of China 2011).

Many countries are spillover countries. Spillover countries include those that produce machinery and vehicles to cut down trees, open roads, grow crops and transport food and forest products. Examples of such countries are Germany and Japan that provide machinery and vehicles to tropical countries like Malaysia and Indonesia to transport forest products. Spillover countries also include those that are affected by the import or export of food and forest products. For example, Singapore and Malaysia are spillover countries related to timber import from Indonesia to China as some of the illegal smuggling routes

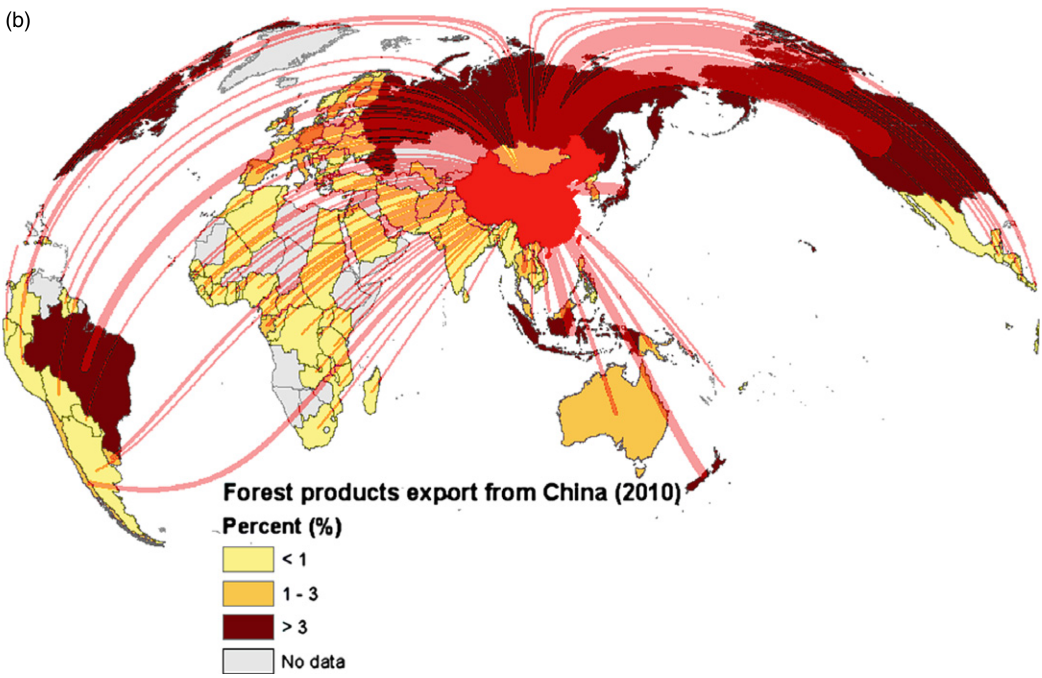
© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

Figure 4 Maps of Imports of Forest Products to China (a) and Exports of Forest Products from China (b). The Countries Are Classified Based on the Percentage of Imported or Exported Value. (Data Sources: FAO)

(a)



(b)

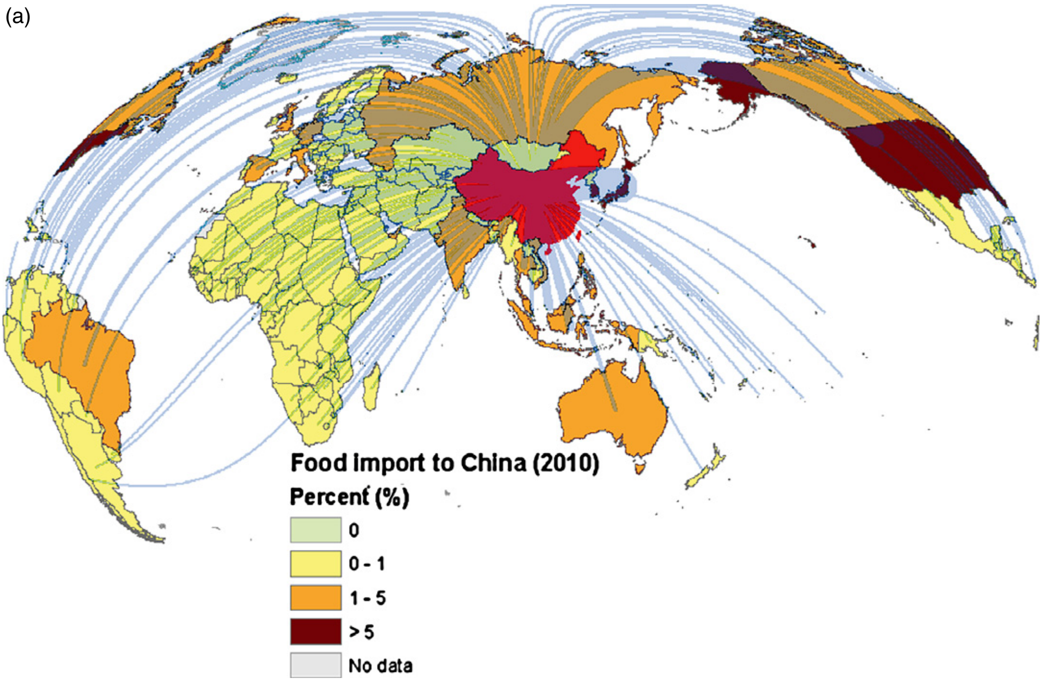


of endangered timber species (e.g. ramin) from Indonesia to China were through Singapore and Malaysia. Singapore's ports are trans-shipment loopholes. There are many sawmills inside Malaysia to produce rough-sawn timber and further processing. Most timber is then re-exported to China and other countries such as Japan and the United States (Lang & Chan

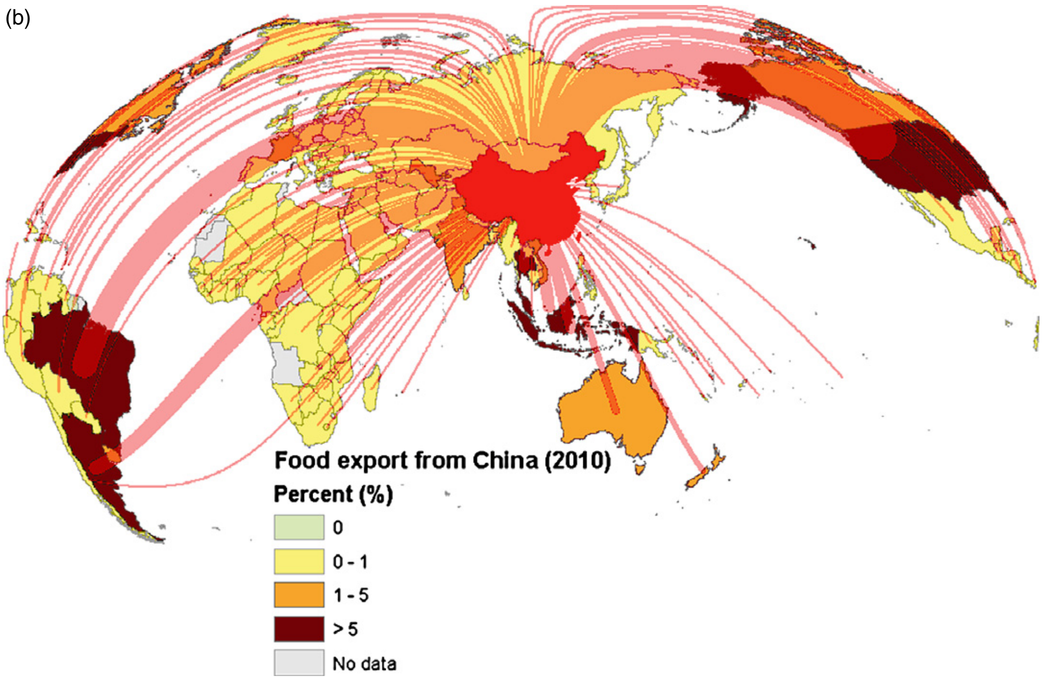
© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

Figure 5 Maps of Imports of Food to China (a) and Exports of Food from China (b). The Countries Are Classified Based on the Percentage of Imported or Exported Value. (Data Sources: FAO)

(a)



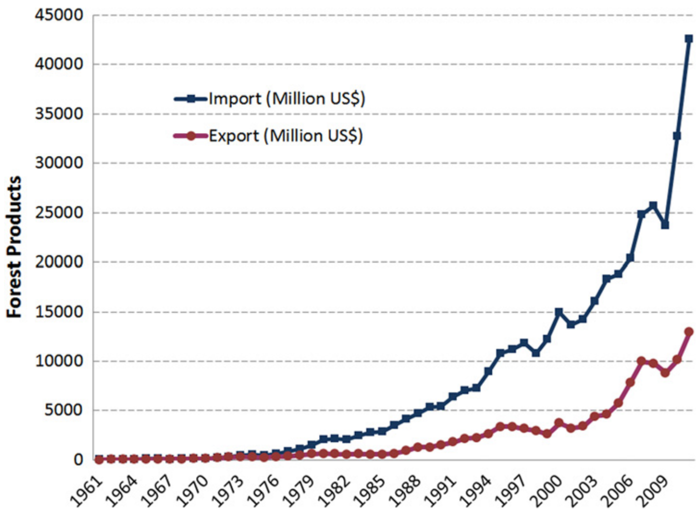
(b)



2006). Thailand and Vietnam are also spillover countries related to timber import from Cambodia to China as logs are trucked through Cambodia, which rests between the two, on their way to China (Lang & Chan 2006). Countries that provide the same product to China could constitute each other's spillover countries when they compete for the Chinese

© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

Figure 6 Flows of Imports and Exports of Forest Products to and from China (Data Sources: FAO)



market. For example, in 2010, China imported soybeans from the United States (with value of $11,328,520,000), Brazil ($8,148,318,000), Argentina ($4,980,289,000), Uruguay ($601,356,000), Canada ($34,627,000), Russia ($203,000), Myanmar ($2,000) and Chile ($1,000). When China imported soybeans from Brazil, other countries such as Argentina and the United States were the spill-over countries because they also sent soybeans to China and were affected by the competition for the same Chinese market.

3.2 Flows

The main flows involved in trade of forest products include forest products transferred from the sending countries to China, and money to purchase the forest products transferred from China to the sending countries. China started to import forest products in the 1960s (Yang et al. 2010) (Figure 6). Before 1999, the flow was basically stable. But after 1999, there was a big increase in the flows as the Chinese government implemented the Natural Forest Conservation Program. For example, in 1998, the forest products from Papua New Guinea (the third biggest tropical forest after the Amazon and Congo basins) to China were 250,000 m^3. This number doubled in 1999, tripled in 2000 and quadrupled in 2001, reaching 1,200,000 m^3 in 2002 (Lang & Chan 2006). By 2008, China had become the second largest importer after the United States, with 103 million m^3 of roundwood equivalent (Global Witness 2009).

The amount of forest products exported from China to other countries was very small compared to the imports (Figure 6). China is the world's largest furniture exporter (Yang et al. 2012). In 2010, China's furniture exports accounted for 27 per cent of the total furniture exports in the world and worth US$10.6 billion, or 58 per cent of China's total furniture exports. The wooden furniture industry grew rapidly, with less than $0.2 billion in 1978, $7.6 billion in 1988, and jumped to $23.2 billion in 2008 (Xia & Yuan 2011). As China's largest importer of wooden furniture, the United States took 32 per cent of China's total exports, followed by Japan (6 per cent), the United Kingdom (Yang et al. 2012) (4 per cent), Canada (3 per cent), and Australia (3 per cent) (Yang et al. 2012).

China was basically self-sufficient in food provision until the early 2000s (Figure 7). Since 2003, the amount of food imports (in terms of value) has greatly exceeded the amount of food exports every year, and the gap has continuously increased over time (Figure 7). In fact, the value of food imports was much higher than the value of forest

© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

Figure 7 Flows of Imports and Exports of Food to and from China (Data Sources: FAO)

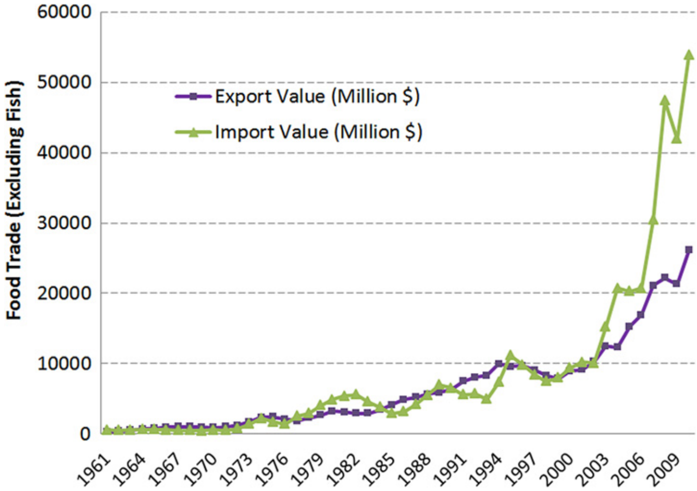
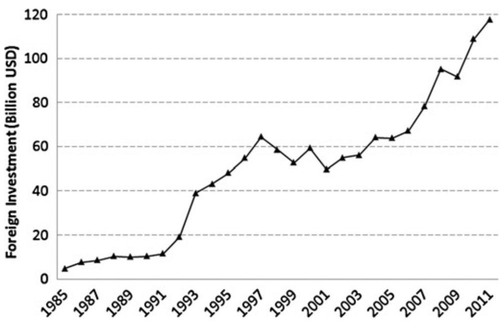


Figure 8 Foreign Investment in China (Data Source: http://www.stats.gov.cn/tjsj/ndsj/2012/html/R0613e.htm, in Chinese)



product imports. For example, in 2010, food imports were worth $68.7 billion and exports were worth $29.8 billion. In contrast, the value of forest products imported was $26.7 billion, and exports were worth $8.5 billion (Figure 7). For both food and forest products, the imports were much higher than exports.

The total foreign investment in China has rapidly and drastically increased over time (from $4.8 billion in 1985 to $117.7 billion in 2011) (Figure 8). The amount of foreign investment in China's forest industry accounted for only a small fraction of the total investment. From 1997 to 2010, there was $8.4 billion invested in forestry, with annual investment of US $0.1 to 1.2 billion a year (360Doc 2010). On the other hand, China has also drastically increased investment in other countries since 2000 when China's 'going out' strategy was formally announced. From 2002 to 2010, China's overseas investment jumped from $2.5 billion to $68.8 billion (Ministry of Commerce of China 2011). Of which, $534 million was invested in forestry, agriculture, husbandry, and fishing industries (Ministry of Commerce of China 2011).

3.3 Agents

Many agents have been involved in investment as well as trade of forest products and food. Most of the agents are private companies, while others are state-owned enterprises (e.g. China National Cereals, Oils and Foodstuffs Import and Export Company, Export–Import Bank of China or Eximbank). For example, Eximbank has hundreds of offices around the world to promote import–export activities. Government agencies such as the Ministry of Commerce and Ministry of Foreign Affairs in China, as well as the China Council for the Promotion of International Trade and Chinese embassies are also important agents as they help companies with relevant information, incentives, legal counsel, deal approval and implementation. Some of the deals were actually initiated by government agencies or encouraged by government policies. For example, the Japanese government has

© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

provided loans to China, and the German government has offered donations to China (360Doc 2010).

Many international organisations facilitate telecouplings. For example, the World Bank, Asian Development Bank and Global Environmental Facility have invested in China's forestry industry for many years (360Doc 2010). National and local elites, such as relatives and friends of government officials, play unique roles (e.g. provision of special access to government officials). As local communities collaborate with companies and elites in exchange for jobs and income to harvest forests, many forests are compromised when incomes from logging are much higher than from other sources (Lang & Chan 2006).

On the other hand, many non-governmental organisations (NGOs) such as Greenpeace, Global Witness, the Center for International Forestry Research, the Environmental Investigation Agency, and World Wildlife Fund, are fighting illegal activities such as illegal logging. They investigate and document illegal activities (using photos and videos) and expose such activities on web sites and in other media (Global Witness 2003, Greenpeace 2005).

3.4 Causes

China's increasing dependence on food and forest product imports is determined by its increasing gap between limited domestic supply and growing demand. Large and fast-growing economies with relatively scarce forest and agricultural resources such as China generate ever increasing demand for food and forest products. For example, burgeoning wealth begets booming demand for wooden housing materials and furniture, which begets more exports of wooden furniture from China to other countries which begets greater demand for forest products (Lang & Chan 2006). When China cannot meet these demands domestically, it looks to other countries for resources, especially those with abundant agricultural land and forests, relatively low population density, and weak land governance (Deininger & Byerlee 2011).

Another cause of importing forest products and food from other countries to China is political. The transition of the political system in China from a socialist to a capitalist, market-driven system paved the way for more freedom to import food and forest products. Successful implementation of food and forest products trade also needed a politically stable environment in both China and exporting countries. Since the 1989 Tiananmen incident, China has experienced a stable political environment (including peaceful transfers of political power at the very top). Countries that export food and forest products to China also have been largely politically stable.

Foreign investment has contributed to China's conservation programs, which in turn have contributed to the decline of domestic forest production and subsequent increase in the imports of forest products. Most of the foreign investment in China's forestry was for afforestation and reforestation (360Doc 2010) and for establishing forestry enterprises to process forest products. The NFCP and the GTGP initiated in the late 1990s (Liu & Diamond 2005; Liu et al. 2008) prompted increases in the imports of forest products and food because NFCP banned the logging of natural forests, and GTGP converted agricultural land to forests or grasslands. While there was a decline in the supply of forest products and food domestically, the demand for forest products and food continued to rise. Thus, forest products and food in other countries became the logical sources to make up the differences. To meet the increasing demand, timber imports have grown rapidly since 1999. For example, there were fewer than 300,000 m^3 (roundwood equivalent) timber imports from Burma to China in 1997 and in 1998, but after the logging ban in China, imports increased to 800,000 m^3 in 2000 and to more than 900,000 m^3 by 2002 (Lang & Chan 2006).

The booming housing market in China in the past decade also pushed the demand for wood higher (e.g. using wood as construction materials). Even from 2008 to 2010 when the world had the worst economic downturn since World War II due to factors such as

© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

the collapse of the housing sector (Toppinen et al. 2010), China's housing market continued to prosper (The Wall Street Journal 2013). Furthermore, the housing area has continued to increase. During 1978–2011, average floor space increase from 6.7 to 32.7 m^2 per capita in urban areas, and from 8.1 to 36.2 m^2 in rural areas (Liu & Diamond 2005; Peterson et al. 2013). Elevated standards of living also increases the demand for interior decorations and furniture (Halstead 2001), thus raising the demand for high quality wood (Natural Resources Canada 2002).

Liberalisation of tariffs in the forest products trade over time, especially after China and major exporting countries joined the World Trade Organization (WTO), has played important roles in promoting forest products trade (Gan 2004). Tariffs on forest products have been lowered a number of times since 1998. For example, maximum tariffs for plywood were reduced from 32.5 per cent in 2001 to 12 per cent in 2009. There are no more tariffs for logs, sawn wood, pulp, and wastepaper (Yang et al. 2010). Non-tariff issues such as standardisation and certification of forest products and national regulations on packaging and recycling of products have begun to influence trade (Toppinen et al. 2010). This is especially true for tropical countries as exporting countries. After the removal of importing licenses in 1999, all interested companies in China can import forest products (Lang & Chan 2006).

3.5 *Effects*

Trading forest products and food is a significant driver of environmental and socioeconomic change. Some studies suggest that importing forest products to China helped increase forest cover in China (Zhu et al. 2004; Rudel et al. 2009; DeFries et al. 2010; Lambin & Meyfroidt 2011). However, it is not clear how much China's increase in forest cover is due to the imported forest products. Here we give a very simple and rough estimate. Assuming the average stock volume is 71 m^3/ha in China (Zhang et al. 2012), importing 528.8 million m^3 of timber from 1994 to 2011 (International Tropical Timber Organization 2012) would have saved 7.4 million ha of forest from harvesting.

Forest harvesting driven by exporting also has led to much environmental damage (e.g. loss of biodiversity, reduction in ecosystem services, soil erosion and floods, (Yang et al. 2013)) in other countries. Exporting forest products and food also exports the nutrients and water embedded in the forest products. China's imports of forest products have been identified as a driving force behind forest loss and degradation in exporting countries of the Asia-Pacific region (Zhu et al. 2004). Forests in many of the exporting countries in Southeast Asia have been declining, although it is not clear how much of the decline is due to harvesting for exports. For example, Indonesia is home to approximately one tenth of the world's remaining tropical forests but has suffered rapid forest loss from a loss of approximately 1.7 million ha per year in the 1980s to more than 2 million ha a year in recent years (Lang & Chan 2006). From 1997 to 2002, approximately 50 million m^3 of forest products were imported from Indonesia to China (Lang & Chan 2006). Assuming that the average forest stock in Indonesia was 110 m^3/ha (the world average) (FAO 2009), then 454,545 ha of forest loss in Indonesia is due to export to China during 1997 to 2002, accounting for roughly 4 per cent of annual forest loss in Indonesia. The same amount of forest that has been saved in China is not the same as the forest that has been cut for exporting to China because the quality of the forest is different. For example, biodiversity in tropical forests is much higher than the temperate forest in China (Liu 2013a).

Adding environmental costs during transport—which can generate a large amount of carbon dioxide—would increase the environmental impacts of telecouplings. However, if farming and forest harvesting in exporting countries are sustainable, then the overall impacts of importing food and forest products can be less than those produced inside importing countries such as China. This is possible as demonstrated in the analysis of environmental impacts of local food production vs. food import (Avetisyan et al. 2013).

© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

The socioeconomic effects of telecouplings are enormous. Producing and selling forest products offer opportunities to enable forest-abundant but otherwise poorer countries to build infrastructure and gain income. To obtain resources, China has invested in socioeconomic infrastructure (e.g. roads, hospitals and schools) in some sending countries. On the other hand, sending forest products to China can jeopardise the livelihoods of the rural poor and increase social conflicts in sending countries. Cutting down trees destroys and fragments the environment, which could undermine local livelihoods that depends on forests for ecosystem services (e.g. fuel, food, water), as well as the potential for the compensation that can come from conservation programs such as the Reducing Emissions from Deforestation and Forest Degradation (REDD) program (The UN-REDD Programme 2013). Producing forest products for exports also can promote an industrial model that creates few jobs for local residents and causes more poverty (Alley et al. 2008; Deininger & Byerlee 2011).

Trade profit can become a source of corruption to relevant government officials in sending countries, making it more difficult to lower the impacts of illegal harvesting (Lang & Chan 2006). Globally, illegal logging may account for 115 to 222 million m^3 raw wood equivalent, or 7 per cent to 13 per cent of the global industrial roundwood production each year. For example, up to one fifth of the timber harvesting in Siberia is illegal (Lang & Chan 2006). Some forest products imported to China from other places such as the Southeast Asia (e.g. Indonesia, Malaysia, Burma, Thailand, Papua New Guinea, the Philippines, Cambodia and Laos) are illegally harvested. China leads the world in the total supply and use of illegally harvested timber (Dieter 2009). More than 90 per cent of the logs and swan wood traded between China and Myanmar is illegal (Global Witness 2009). As much as 50 million m^3 of timber produced in Indonesia is illegally harvested, in places such as the world-renowned Tanjung Puting National Park (a UNESCO Biosphere Reserve established in 1977) (Lang & Chan 2006). Most of the illegal timber was exported to China and developed countries including the United States, Japan and Europe. Furthermore, China exports furniture and plywood produced using illegally harvested timber to places such as the EU and the United States (Lang & Chan 2006). Illegal harvesting activities do not follow a sustainable forest management plan and cause the government to lose revenues, in addition to environmental impacts such as loss of biodiversity and carbon storage and desertification (Dieter 2009).

Socioeconomic and environmental consequences of exporting forest products, especially from tropical countries with high biodiversity, have caused widespread attention in the global news media. Such attention has generated various feedbacks. For example, in response to the problem of illegal harvesting, many sending countries have implemented forest certification programs to prevent illegally harvested forest products from being exported to countries such as China (Owari et al. 2006). Forest certification is a mechanism to regulate the trade of forest products by 'credibly identifying well-managed forests as the sources of responsibly produced wood products' implemented by the Forest Stewardship Council (Forest Stewardship Conicil International Center 2013). Certified companies have tended to enhance a positive public image and increase customer satisfaction and retention rates (Owari et al. 2006). Worldwide, more than 306 million ha of forests had been certified as of June 2007. While China is a later comer in adopting forest certification, the Forest Stewardship Council had certified 17 forest management enterprises, and over 1 million ha of forests in China by July 2009 (Zhao et al. 2011). Many feedbacks are unknown. For example, it is not clear how much the CO_2 emissions associated with telecouplings affect China and other countries involved. This is an example of a hidden issue that the telecoupling framework can help identify for future research.

3.6 Interactions among Telecouplings

Different types of telecouplings interact. Telecoupling processes such as foreign investment in China's forests may increase the

© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

import of forest products, as the investment creates more forest enterprises that use more forest products to make wooden furniture and other products. Although foreign investment also helps China's effort in reforestation and afforestation, the pace to produce forest products needed for the forest enterprises is slower than the demand. However, food imports may reduce the import of forest products in the long run as they help free more agricultural land for forest restoration in China but reduce forests in other countries.

There are also cross-scale interactions among telecouplings, i.e. interactions among telecouplings at different scales. While the above discussion focused on the global telecouplings (e.g. through trade among continents) and continental telecouplings (e.g. through trade among countries in Asia), there are also national and regional telecouplings within China. For example, within China, there are three regions based on imports and exports of forest products: forest product exporting region that provides forest products (e.g. Heilongjiang, Inner Mongolia and Jilin in Northeast China; and Fujian, Guangxi, Jiangxi and Yunnan provinces in South and Southwestern China), forest product importing region that receives forest products (e.g. Beijing, Hebei, Shanxi and Tianjin in North China; Jiangsu, Shandong and Shanghai in East China; Henna and Hubei in Central China; and Gansu, Ningxia, Qinghai, Shaanxi and Xinjiang in Northwest China); and forest product self-sufficient region (e.g. Guizhou, Hunan, Sichuan, Tibet and Zhejiang) (Cheng et al. 2010). The imported forest products from other countries have mainly gone to the forest product importing region and thus reduce the imports of forest products from the exporting region within China (i.e. global and continental telecouplings weaken national telecouplings). Within each region, there are variations in availability and demand for forest products. For example, in the exporting region, cities (e.g. the city of Harbin in Heilongjiang) import forest products from other areas in the region (i.e. regional telecouplings). Such demand within the exporting region may reduce the amount of forest product exports to the importing region (i.e. regional telecouplings may weaken national telecouplings). Within a local area near the forest of the exporting region, local residents may cut down trees in the forest for fuelwood and material for construction and furniture, thus reducing the potential for forest products to be exported to cities within the region and to the importing region. In other words, local telecouplings may weaken regional and national telecouplings but may strengthen global and continental telecouplings.

4. Promoting China's Forest Sustainability with Maximum Positive Global Impacts

In this section, we discuss China's forest sustainability in the context of future demand and supply, and offer policy recommendations under the telecoupling framework.

4.1 Perspectives on Future Demand and Supply

In the next several decades, China's demand for food and forest products will continue to increase for several reasons. China's population size and household number are projected to reach 1.45 billion and 645 million by 2030, respectively (United Nations 2001; Liu 2013b). Household numbers will continue to increase faster than population sizes because of factors such as increased divorces (Yu & Liu 2007). Chinese diet is shifting towards more meat products, which consume more resources. The rapid urbanisation will likely accelerate as many more people would like to be in cities, and there are still about 650 million rural residents. The Chinese government is aggressively promoting more urbanisation, as urbanisation is a major engine of economic growth, which will lead to rapid infrastructure development, building construction and furniture manufacturing. These and other factors will all drive even more increases in the demand for food and forest products and the conversion of forested areas into residential areas and infrastructure (e.g. roads). On the other hand, abandonment of

© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

farm land as a result of rural people migrating to cities will increase forest cover in rural areas (Chen et al. 2012). In fact, many rural areas have shown rapid recovery of vegetation, including forests (Tuanmu et al. 2010). Perhaps in a few decades, more timber will be available in rural areas that have a large labour migration to cities.

Many economic models calculate per capita consumption of forest products as a function of national income per capita. Zhang et al. (1997) argue that this type of relationship is particularly useful for developing countries. Although prices are not considered as part of consumption, the income level may in part incorporate the price factor, and price level is often linked with income. As the economy grows, prices usually go up. A simple projection based on the annual rate of increase in average timber demand between 1998 and 2008 indicates that China will need 678 million m^3 of timber by 2020 (Yang et al. 2010). It is projected that China's timber demand for use in construction will be 480 million m^3; 190 million m^3 of this will be imported (Yang & Nie 2008).

Despite China's increase in forest cover, forest coverage is still low by world standards (Liu & Diamond 2005). There are only 3.04 million km^2 of forest (State Forestry Administration of China 2010; Yang et al. 2010) or 20.36 per cent of China's land area (or about two thirds of the world average, which is approximately 31 per cent of the land area (Barbu 2011)), or 0.2 ha per capita in China, which is one third of the 0.6 ha per capita world average (FAO 2010; Liu & Raven 2010). To fight climate change and sequester carbon dioxide, the Chinese government has announced intentions to increase forest cover to 21.66 per cent by 2015 (China Council for International Cooperation on Environment and Development 2012) and further increase forest cover by 40 million ha by 2020 (Xinhuanet 2011). After 2020, there is an increasing limitation on available land for afforestation, as there is increasing competition for land (Liu & She 2012).

While it is good to increase forest coverage, there is also a strong need to increase forest stocks. The total forest stock is only 13.71 billion m^3 (or about 10.15 m^3 per capita, one seventh of the world average (Yang et al. 2010)). The unit volume in China is only three quarters of the world average (86 m^3/ha vs. 110 m^3/ha) (FAO 2009). In another estimate, the stock density is even lower (only 71 m^3/ha, about half the world average) (Zhang et al. 2012). Thus, timber supply in China's forests is very limited and will remain limited for many years to come.

The timber plantations program initiated by the government was designed to increase domestic timber supply and reduce timber imports. Even if everything goes as planned, the program can meet only 40 per cent of the timber demand, as the program can produce only 133 million m^3 of logs per year by 2015 (Lu 2004). It is hoped that this program, together with other plantations and natural forest areas exempt from the logging ban, can meet China's future demand for timber (Lu 2004). But no one is certain if or when this can occur.

China's forest sustainability also will depend on the forest conditions in other countries. If the resources elsewhere are limited, the opportunities for China to import will diminish and become more expensive. Such prospects may exist if previous patterns continue. For example, from 2005 to 2010, the world lost 27.9 million ha of forests (FAO 2010). Such reduction was particularly pronounced in developing countries such as Indonesia and Malaysia, which are among the major countries that provide forest products to China.

4.2 Policy Recommendations

The widening gap between China's domestic supply and demand of forest and food products indicates the increasing dependence on telecouplings. The implications of such telecouplings between China and the rest of the world are huge but remain uncertain. The telecoupling framework can provide useful guidance to minimise negative effects and enhance positive effects. Many suggestions have been made regarding forest management in China (e.g. promoting natural recovery, continuing to implement the Forest Industrial

© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

Base Development Program in key regions with the focus on fast-growing and high-yield timber plantations to produce more timber in China (Lu 2004; Liu et al. 2013a, 2013b), but telecouplings have not been systematically incorporated into policy. Below, we offer several policy recommendations related to telecouplings.

Incorporate Spillover Countries

As spillover countries are common, it is important to go beyond bilateral or multilateral agreements and trade partners that often focus on sending and receiving countries only. Many international agreements are bilateral (e.g. between importing and exporting countries only), which rarely consider spillover countries. For example, China has signed bilateral memorandums of understanding with countries such as Indonesia to establish a bilateral forum on combating illegal logging and associated trade. China is signatory to many multilateral international treaties related to forest management and trade, such as the Convention on International Trade in Endangered Species, the Ramsar Convention, the Convention on Biological Diversity, the United Nations Convention to Combat Desertification, the United Nations Framework Convention on Climate Change and other international mechanisms (Chen 2010).

Through cooperation with international organisations such as the United Nations Food and Agriculture Organization (FAO) and the International Tropical Timber Organization (ITTO), and the NGOs (e.g. World Conservation Union, The Nature Conservancy, World-wide Fund for Nature and Forest Trends), China has provided support to international efforts. It is encouraging that the Chinese government has issued guidelines on sustainable forest management and utilisation to guide Chinese enterprises outside China to cultivate and use forests based on the principles of sustainable development. However, it is important to implement the guidelines and minimise the negative effects on sending countries and spillover countries. An international public comment period would be useful to identify and evaluate spillover countries as a result of international agreements (similar to public comment periods for many public policies in the United States).

Nurture Sending Countries

The sending countries that provide forest products are relatively concentrated. For example, between 1998 and 2008, 80 per cent of the total timber imports were from five countries (Russia, Malaysia, Papua New Guinea, New Zealand and Gabon). Importing timber from a small number of countries with poor social and environmental practices has generated widespread concern over excessive use of forests in those countries (Yang et al. 2010). Many countries (e.g. Indonesia, Thailand, Laos, Vietnam and Cambodia) have passed natural forest harvesting peaks (Katsigris et al. 2004). Thus, it is in China's long-term interest to nurture forests in exporting countries and ensure that global forests are sustainable. China may offer to help with restoration of natural forests and productive plantations to have sustainable supplies. One way to help is to provide payments for ecosystem services (or fully compensate the damage as a result of forest harvesting and farming for export to China). Another approach is to encourage selective logging in less environmentally sensitive areas to obtain forest products while keeping forests sustainable (Edwards & Laurance 2013). Diversifying sending countries and increasing imports of forest products from countries with good environmental and social practices and with rich forest resources, such as northern Europe, may reduce negative environmental and social impacts.

Anticipate Multiple Telecouplings

Our analysis indicates that trade of forest products is just one of the telecouplings that affect China, exporting countries and spillover countries. Other types of telecouplings such as the trade of food and foreign investment are also important if not more important than the trade of forest products. Technology transfer and knowledge dissemination can help increase the efficiency of resource use and thus reduce the consumption of forest products. Furthermore, different types of telecouplings may interact

© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

with each other. Unless the unit area yield is high enough to meet domestic needs, reducing land for other activities (e.g. agriculture and mining) in China may require importation of more food and mineral resources, which may directly and indirectly reduce forests elsewhere.

Embrace Feedbacks

The telecoupling framework emphasises the role of feedbacks. For example, an important feedback to reduce deforestation is the development and implementation of policy to prevent illegal harvesting through forest certification. The process of implementing forest certification in China has great potential and may be speeded up by increasing public awareness, enhancing management flexibility and reducing certification cost (Zhao et al. 2011). China should consider launching an action plan similar to that of the EU to combat illegal harvesting—the Forest Law Enforcement, Governance and Trade (FLEGT). A major component of this action plan is to confine or possibly stop imports of illegally harvested timber (European Union 2005). China's active participation in the regional FLEGT processes in Asia, Europe and North Asia would help to minimise illegal harvesting. Innovative measures are needed to address unidentified feedbacks such as impacts of CO_2 emissions associated from telecouplings.

Fill Knowledge Gaps on Telecouplings

Research on telecouplings is still in its infancy. Many questions remain unanswered, and many things remain unknown. For example, how much gain in China's forest is offset by the loss of forest and biodiversity in other countries? How much ecosystem services are gained by reforestation in China and how much services are lost by deforestation in countries that China is importing forest products from? Ecosystem services that forests provide to humans are enormous (Millennium Ecosystem Assessment 2005; Yang et al. 2013), such as wildlife habitat (Xu et al. 2006b; Lepczyk et al. 2008), cultural values (He et al. 2008) and provisioning of food and water (Liu & Yang 2012) The effects of telecouplings on other ecosystem services probably outweigh the economic values of timber and timber products.

Data on spillover countries are especially lacking. In many cases, even what spillover countries are is unknown, let alone the impacts on them. Also, identifying feedbacks is particularly challenging. This is due in part to feedbacks usually taking a long time (e.g. many years to decades or centuries) to emerge while most research projects are of short durations (e.g. months or a few years). Many issues (e.g. time lag, legacy effect, non-linearity, thresholds, cross-scale interactions and interactions among different types of telecouplings) are clear at the conceptual level, but quantitative information (e.g. relative contributions of different telecouplings to forest sustainability, interactions between telecouplings and local couplings) is needed. Such information is crucial for better understanding and managing telecouplings for local to global sustainability. Big data tools and cloud computing may play important roles in the study and management of telecouplings.

5. Concluding Remarks

The telecoupling framework provides a systematic understanding of China's forest sustainability and impacts on other countries. It helps identify knowledge gaps and hidden issues such as spillover countries, feedbacks and interactions among telecouplings of different types and at different scales, which have received little explicit attention in previous research on trade, investment, knowledge dissemination, technology transfer, sustainability, forestry, ecosystem services, human well-being and land use. It offers a good analytic lens to understand socioeconomic and environmental interactions across the world. Such an approach can help facilitate different institutions and agents worldwide to cooperate in addressing socioeconomic and environmental challenges. Making forests sustainable needs to go beyond forests and beyond trading and investing partners. With its increasing economic power, China has the opportunity to take a leadership role in addressing telecouplings.

© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

Together with the global community, it is possible that China can continue sustaining forests with maximum positive global impacts in the telecoupled world.

November 2013

References

360Doc (2010) Foreign investment in China's forestry from 2002–2009—A02.

Alley P, Bermann C, Danielson L, et al. (2008) *To Have and Have Not*. Heinrich Böll Foundation, Berlin.

Avetisyan M, Hertel T, Sampson G (2013) Is Local Food More Environmentally Friendly? The GHG Emissions Impacts of Consuming Imported versus Domestically Produced Food. *Environmental and Resource Economics* doi: 10.1007/s10640-013-9706-3

Barbu M (2011) Current Developments in the Forestry and Wood Industry. *Pro Ligno* 7, 111–24.

Bearer S, Linderman M, Huang JY, An L, He GM, Liu JQ (2008) Effects of Fuelwood Collection and Timber Harvesting on Giant Panda Habitat Use. *Biological Conservation* 141, 385–93.

Bertalanffy LV (1969) *General System Theory: Foundations, Development, Applications*. George Braziller Inc., New York.

Chen XD, Lupi F, Vina A, He GM, Liu JG (2010) Using Cost-Effective Targeting to Enhance the Efficiency of Conservation Investments in Payments for Ecosystem Services. *Conservation Biology* 24, 1469–78.

Chen XD, Frank KA, Dietz T, Liu JG (2012) Weak Ties, Labor Migration, and Environmental Impacts: Toward a Sociology of Sustainability. *Organization & Environment* 25, 3–24.

Chen Y (2010) Forest Law Enforcement and Governance in the People's Republic of China. In: Pescott MJ, Durst PB, Leslie RN (eds) *Forest Law Enforcement and Governance: Progress in Asia and the Pacific*, pp. 85–95. FAO, Regional Office for Asia and the Pacific, Bangkok.

Cheng S, Xu Z, Su Y, Zhen L (2010) Spatial and Temporal Flows of China's Forest Resources: Development of a Framework for Evaluating Resource Efficiency. *Ecological Economics* 69, 1405–15.

China Council for International Cooperation on Environment and Development (2012) China promotes sustainable forest management, striving to bring the forest coverage up to 21.66% by 2015.

CSIL Center for Industrial Studies (2009) *World Furniture Outlook Summary*. Milano MI, Italy.

DeFries RS, Rudel T, Uriarte M, Hansen M (2010) Deforestation Driven by Urban Population Growth and Agricultural Trade in the Twenty-First Century. *Nature Geoscience* 3, 178–81.

Deininger KW, Byerlee D (2011) *Rising Global Interest in Farmland: Can It Yield Sustainable and Equitable Benefits?* World Bank, Washington, DC.

Dieter M (2009) Analysis of Trade in Illegally Harvested Timber: Accounting for Trade via Third Party Countries. *Forest Policy and Economics* 11, 600–7.

Edwards DP, Laurance WF (2013) Biodiversity Despite Selective Logging. *Science* 339, 646–7.

European Union (2005) *Council Regulation (EC) no. 2173/2005 of 20 December 2005 on the Establishment of a FLEGT Licensing Scheme for Imports of Timber into the European Community*. Official Journal of the European Union.

FAO (2009) *State of the World's Forests*. FAO Communication Division, Rome, Italy.

FAO (2010) *Global Forest Resources Assessment 2010: Main Report*. Food and Agriculture Organization of the United Nations, Rome, Italy.

Forest Stewardship Conicil International Center (2013) *A Global, Not-For-Profit Organization Dedicated to the Promotion of Responsible Forest Management Worldwide*, viewed December 2013 <https://ic.fsc.org/index.htm>.

Gan J (2004) Effects of China's WTO Accession on Global Forest Product Trade. *Forest Policy and Economics* 6, 509–19.

© 2013 The Author. *Asia and the Pacific Policy Studies*

Glantz MH, Katz RW, Nicholls N (1991) *Teleconnections Linking Worldwide Climate Anomalies*. Cambridge University Press, Cambridge, England; New York.

Global Witness (2003) *A Conflict of Interests: The Uncertain Future of Burma's Forests: A Briefing Document*. Global Witness, London, UK.

Global Witness (2009) *A Disharmonious Trade: China and the Continued Destruction of Burma's Northern Frontier Forests*. Global Witness, London, UK.

Greenpeace (2005) *Partners in Crime: The U.K Timber Trade, Chinese Sweatshops and Malaysian Robber Barons in Papua New Guinea's Rainforests*. London, UK.

Halstead T (2001) *China Solid Wood Products Market Update*. USDA.

He GM, Chen XD, Liu W, et al. (2008) Distribution of Economic Benefits from Ecotourism: A Case Study of Wolong Nature Reserve for Giant Pandas in China. *Environmental Management* 42, 1017–25.

International Tropical Timber Organization (2012) *Annual Review and Assessment of the World Timber Situation 2011* viewed December 2013 <http://www.itto.int/annual_review_output>.

Katsigris E, Bull GQ, White A, et al. (2004) The China Forest Products Trade: Overview of Asia-Pacific Supplying Countries, Impacts and Implications. *International Forestry Review* 6, 237–53.

Lambin EF, Meyfroidt P (2011) Global Land Use Change, Economic Globalization, and the Looming land Scarcity. *Proceedings of the National Academy of Sciences of the United States of America* 108, 3465–72.

Lang G, Chan CHW (2006) China's Impact on Forests in Southeast Asia. *Journal of Contemporary Asia* 36, 167–94.

Lepczyk CA, Flather CH, Radeloff VC, Pidgeon AM, Hammer RB, Liu JG (2008) Human Impacts on Regional Avian Diversity and Abundance. *Conservation Biology* 22, 405–16.

Levitt T (1982) *The Globalization of Markets*. Division of Research, Graduate School of Business Administration, Harvard University, Boston.

Linderman MA, An L, Bearer S, He GM, Ouyang ZY, Liu JG (2005) Modeling the Spatio-Temporal Dynamics and Interactions of Households, Landscapes, and Giant Panda Habitat. *Ecological Modelling* 183, 47–65.

Liu J (2010) China's Road to Sustainability. *Science* 328, 974.

Liu J (2013a) Complex Forces Affecting China's Biodiversity. In: Sodhi NS, Gibson L, Raven P (eds) *Conservation Biology: Lessons from the Tropics*, pp. 207–15. Wiley-Blackwell, Oxford.

Liu J (2013b) Effects of Global Household Proliferation on Ecosystem services. In: Fu B, Jones B (eds) *Landscape Ecology for Sustainable Environment and Culture*, pp. 103–18. Springer, the Netherlands.

Liu J, Daily GC, Ehrlich PR, Luck GW (2003) Effects of Household Dynamics on Resource Consumption and Biodiversity. *Nature* 421, 530–3.

Liu J, Diamond J (2005) China's Environment in a Globalizing World. *Nature* 435, 1179–86.

Liu J, Dietz T, Carpenter SR, et al. (2007a) Complexity of Coupled Human and Natural Systems. *Science* 317, 1513–6.

Liu J, Dietz T, Carpenter SR, et al. (2007b) Coupled Human and Natural Systems. *AMBIO: A Journal of the Human Environment* 36, 639–49.

Liu J, Hull V, Batistella M, et al. (2013a) Framing Sustainability in a Telecoupled World. *Ecology and Society* 18, 26, viewed December 2013 <http://dx.doi.org/10.5751/ES-05873-180226>.

Liu J, Li S, Ouyang Z, Tam C, Chen X (2008) Ecological and Socioeconomic Effects of China's Policies for Ecosystem Services. *Proceedings of the National Academy of Sciences of the United States of America* 105, 9477–82.

Liu J, Linderman M, Ouyang Z, An L, Yang J, Zhang H (2001) Ecological Degradation in Protected Areas: The Case of Wolong Nature Reserve for Giant Pandas. *Science* 292, 98.

Liu J, Ouyang Z, Yang W, Xu W, Li S (2013b) Evaluation of Ecosystem Service Policies

© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

from Biophysical and Social Perspectives: The Case of China. In: Levin SA (ed) *Encyclopedia of Biodiversity*, pp. 372–84. Academic Press, Waltham, MA.

Liu J, Raven PH (2010) China's Environmental Challenges and Implications for the World. *Critical Reviews in Environmental Science and Technology* 40, 823–51.

Liu Y, She G (2012) Chinas Forest Resource Dynamics Based on Allometric Scaling Relationship between Forest Area and Total Stocking Volume. *African Journal of Agricultural Research* 7, 4971–78.

Liu M, Tian H (2010) China's Land Cover and Land Use Change from 1700 to 2005: Estimations from High-Resolution Satellite Data and Historical Archives. *Global Biogeochemical Cycles* 24 GB3003. doi: 10.1029/2009GB003687

Liu J, Tian H, Liu M, Zhuang D, Melillo JM, Zhang Z (2005) China's Changing Landscape During the 1990s: Large-Scale Land Transformations Estimated with Satellite Data. *Geophysical Research Letters* 32, L02405.

Liu J, Yang W (2012) Water Sustainability for China and Beyond. *Science* 337, 649–50.

Liu J, Yang W (2013) Integrated Assessments of Payments for Ecosystem Services Programs. *Proceedings of the National Academy of Sciences of the United States of America* 110, 16297–8.

Lu W (2004) China's Growing Role in World Timber Trade. *Unasylva* 55, 27–31.

Mather AS (1992) The Forest Transition. *Area—Institute of British Geographers* 24, 367.

Meyfroidt P, Lambin EF (2011) Global Forest Transition: Prospects for an End to Deforestation. *Annual Review of Environment and Resources* 36, 343–72.

Millennium Ecosystem Assessment (2005) *Ecosystems & Human Well-Being: Synthesis*. Island Press, Washington, DC.

Ministry of Commerce of China (2011) *2010 Statistical Bulletin of China's Outward Foreign Direct Investment*, viewed December 2013 <http://images.mofcom.gov.cn/hzs/accessory/201109/1316069658609.pdf>.

Montgomery JD (1992) Job Search and Network Composition: Implications of the Strength-of-Weak-Ties Hypothesis. *American Sociological Review* 57, 586–96.

Natural Resources Canada (2002) Opportunities for Canadian Wood Products in Selected Pacific Rim Markets.

NSF Advisory Committee for Environmental Research and Education (2009) Transitions and Tipping Points in Complex Environmental Systems.

Owari T, Juslin H, Rummukainen A, Yoshimura T (2006) Strategies, Functions and Benefits of Forest Certification in Wood Products Marketing: Perspectives of Finnish Suppliers. *Forest Policy and Economics* 9, 380–91.

Peterson N, Peterson T, Liu J (2013) *The Housing Bomb*. Johns Hopkins University Press, Baltimore, MD.

Rudel TK (1998) Is There a Forest Transition? Deforestation, Reforestation, and Development. *Rural Sociology* 63, 533–52.

Rudel TK (2005) Forest Transitions: Towards a Global Understanding of Land Use Change. *Global Environmental Change: Human and Policy Dimensions* 15, 23–31.

Rudel TK, Schneider L, Birkenholtz T, et al. (2009) Agricultural Intensification and Changes in Cultivated Areas, 1970–2005. *Proceedings of the National Academy of Sciences of the United States of America* 106, 20675–80.

Shapiro J (2001) *Mao's War against Nature: Politics and the Environment in Revolutionary China*. Cambridge University Press, Cambridge; New York.

State Forestry Administration of China (2010) *Three-North Shelterbelt Forest Program*.

The UN-REDD Programme (2013) *The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries*, viewed December 2013 <http://www.un-redd.org>.

The US-China Business Council (2007) *Foreign Investment in China*.

© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University

The Wall Street Journal (2013) China Property Market Grew in 2012, viewed December 2013 <http://online.wsj.com/news/articles/SB10001424127887323468604578249193345078874>.

Toppinen A, Zhang YQ, Geng W, et al. (2010) Changes in Global Markets for Forest Products and Timberlands. *IUFRO World Series* 25, 137–56.

Tuanmu MN, Vina A, Bearer S, et al. (2010) Mapping Understory Vegetation Using Phenological Characteristics Derived from Remotely Sensed Data. *Remote Sensing of Environment* 114, 1833–44.

United Nations (2001) *Cities in a Globalizing World. Earthscan*. Sterling, London.

World Commission On Environment and Development (1987) *Our Common Future*. Oxford University Press, Oxford, NY.

Xia L, Yuan J (2011) Study on the Development of Chinese Modern Furniture Industry. *Enterprise Economics* 372, 86–8.

Xinhuanet (2011) *President Hu: China To Increase Forest Area by 40 Million Hectares*, viewed December 2013 <http://news.xinhuanet.com/english2010/china/2011-09/06/c_131106358.htm>.

Xu J, Yin R, Li Z, Liu C (2006a) China's Ecological Rehabilitation: Unprecedented Efforts, Dramatic Impacts, and Requisite Policies. *Ecological Economics* 57, 595–607.

Xu WH, Ouyang Z, Vina A, Zheng H, Liu JG, Xiao Y (2006b) Designing a Conservation Plan for Protecting the Habitat for Giant Pandas in the Qionglai Mountain Range, China. *Diversity and Distributions* 12, 610–9.

Yang H, Nie Y (2008) Analysis of China's Timber Supply and Demand Structure. *World Agriculture* 351, 53–6.

Yang H, Nie Y, Ji C (2010) Study on China's Timber Resource Shortage and Import Structure: Natural Forest Protection Program Outlook, 1998 to 2008. *Forest Products Journal* 60, 408–14.

Yang H, Ji C, Nie Y, Hong Y (2012) China's Wood Furniture Manufacturing Industry: Industrial Cluster and Export Competitiveness. *Forest Products Journal* 62, 214–21.

Yang W, Dietz T, Liu W, Luo JY, Liu JG (2013) Going Beyond the Millennium Ecosystem Assessment: An Index System of Human Dependence on Ecosystem Services. *PLoS ONE* 8, e64581. doi: 10.1371/journal.pone.0064581

Yu E, Liu JG (2007) Environmental Impacts of Divorce. *Proceedings of the National Academy of Sciences of the United States of America* 104, 20629–34.

Zhang H, Buongiorno J, Zhu S (2012) Domestic and Foreign Consequences of China's Land Tenure Reform on Collective Forests. *International Forestry Review* 14, 349–62.

Zhang Y, Buongiorno J, Zhang D (1997) China's Economic and Demographic Growth, Forest Products Consumption, and Wood Requirements: 1949 to 2010. *Forest Products Journal* 47, 27.

Zhao J, Xie D, Wang D, Deng H (2011) Current Status and Problems in Certification of Sustainable Forest Management in China. *Environmental Management* 48, 1086–94.

Zhu C, Taylor R, Feng G (2004) *China's Wood Market, Trade and the Environment*. Science Press USA Inc., Monmouth Junction, NJ.

© 2013 The Author. *Asia and the Pacific Policy Studies*
published by Wiley Publishing Asia Pty Ltd and Crawford School of Public Policy at The Australian National University