Telecoupling in ecosystem services: a case study of Xishuangbanna

Zhuoya Zhang[1, 2, a], Nanjun Lang[3, b], Wen Ye[1, c], Xin Yang[4, d, *]

[1]Faculty of Environmental Science and Engineering, Kunming University of Science and Technology, Yunnan, China

[2]School of Geography and Ecotourism, Southwest Forestry University, Yunnan, China

[3]Faculty of Ecology and Environment, Southwest Forestry University, Yunnan, China

[4]Communist Youth League Committee, Southwest Forestry University, Yunnan, China

[a]zhangzhuoya2011@163.com, [b]nanjunlang@126.com, [c]ywenyn@qq.com, [d]670708058@qq.com

*Corresponding author

Keywords: Ecosystem services (ES), Xishuangbanna, tele coupling

Abstract: Ecosystem services (ES) are a fundamental and important part of ecology. Recently, the study of ES has intensified, but research on ES over distances is still lacking. The integration of different types of ES into the tele coupling framework is not in widespread use due to the socioeconomic and environmental interactions over distances. In this study, we present a tele coupling framework to analyse the coupled human and natural systems of Xishuangbanna, Southwest China, which has the highest typical tropical forest cover in China and a large amount of biodiversity. We followed the ES types and analysed their tele couplings. By employing a tele coupling analysis, we studied the tele coupling of provisioning service systems, regulating service systems, and culture services. We differentiated between systems, flows, agents, causes, and effects in every ES type. Further research on tele coupling within ES might facilitate a better understanding of distance between ES and enhance coupled human and nature system in complex global interactions.

1. Introduction

Nature provides human society with a vast array of benefits such as food, fibers, clean water, healthy soil, carbon capture, and many others [1]. Human well-being is entirely dependent upon the continued flow of ecosystem services (ES), which provide a range of services that are fundamental to humankind's health, livelihood, and survival [2-5].

ES are the benefits that people obtain from ecosystems. These services are predominantly public goods with no markets and no prices, so they are rarely detected by our current economic compass 1and their values are not considered by global economic policy decisions. As a result, the threats of habitat destruction, environmental pollution, over-exploitation by humans, and invasive species cause an unprecedented loss of biodiversity and ES. This might lead to tremendous costs for societies due to the subsequent loss of various provisional and regulatory services such as food production, water regulation, and climate change resilience [4]. The destruction of biodiversity and ES have now reached levels where serious social and economic costs are being observed and will be continue to be observed at an accelerating pace if we continue with our current activity.

The United Nations started the Millennium Ecosystem Assessment in 2001, which was the first time our society assessed the ecosystem services' history, current situation, change in trend on a worldwide scale, and also discussed the driving factors for these changes as well as the impacts they have on our well-being. The value of ES has attracted more attention in last decade. The Economics of Ecosystems and Biodiversity (TEEB) project plan which aims to promote a better understanding of the true economic value of ecosystem services, offers economic tools to take proper account of ES value and some achievements on the study of the theory and methods have been obtained. The key

point on which we focus is the link between socioeconomic benefits and ES, in particular that of coupled human and natural systems (CHANS).

There is great demand for evaluating the value of ES to human well-being. Most researchers focus on exposing the values of nature. They have made tremendous progress in driving the advancement of decision-making to consider the values of biodiversity and ES. Many ES including food, fuel, and clean water are produced locally, but their benefits extend regionally, nationally, and even globally [6]. Although distance factors have been mentioned, there is a need for a new research framework in order to fill in knowledge gaps and advance sustainability science and its application [7-8]. The umbrella concept of ES encompasses a variety of nature's benefits to humans and facilitates studies on relationships among different types of services [9-10]. Similarly, the framework of tele coupling can help promote systematic, multidisciplinary studies on different types of distant interactions and their interrelationships. Around the globe, previously isolated localities are rapidly forming connections over increasing spatial extents through the flow of ES [6].

Interactions between socioeconomic benefits and ES are generally studied on a local level. Although such studies have generated important insight, they do have limitations, especially with increasing globalization and trade. On this basis, we identify a need to explore the interconnections over distances between provisioning, regulating, supporting, and cultural services provided by ecosystems [3]. These are the typical groups of different types of ecosystem services.

Tele coupling is socioeconomic and environmental interactions over distances [11]. Distant interactions increasingly affect globally important issues such as climate change, biodiversity, food security, land use, and so on [11]. The concept goes deeper and extends further than local interactions and coupling because globalization has intensified global interconnectedness, which has rapidly increased the connection between social-ecological systems across distant regions.

Here we apply the emerging tele coupling framework to systematically analyze the causes, agents, effects, flows, and systems of ES. The tele coupling framework provides a lens and method with which to evaluate human well-being and ecosystem interactions in linked systems across spatial distances. It can also help analyze the interrelationships of ES and human well-being, providing a useful means of incorporating feedback as well as multiple systems (sending, receiving, and spillover systems) into interactions.

We attempt to address these socioeconomic benefits and ES interactions increase issues by first elaborating on the framework of tele coupling for different types of ecosystem services. We illustrate our point using Xishuangbanna's ecosystem services. Our research aims are to (1) identify the interaction between natural and human components over distances, (2) determine how the framework of tele coupling works on different types of ES, and (3) identify the workings of tele coupling components, such as the systems, flows, agents, causes, and effects.

2. Methods

2.1 ES under the tele coupling framework

Population expansion, consumption growth, and energy demands are all likely to significantly increase in the coming decade, which will then demand more from ES.

ES and human societies are unevenly distributed across landscapes [3, 11-12], and the divergence between the supply of and demand for ES is increasing [13]. ES are not limited to local services for human well-being; almost all ES occur in socioeconomic and environmental interactions over distances from the provisioning, transfer, and benefits to humans. They interact in complex ways, often via sending, receiving, and spillover.

The systems approach of tele coupling emphasizes linked CHANS over spatial distances and aims to integrate analyses of socioeconomic benefits and ES flows among interacting systems in order to evaluate holistically sustainability [6, 11]. According to Liu et al., there are five main, interrelated components of tele coupling: (1) systems that refer to CHANS or integrated systems in which humans and nature interact [14], for each tele coupling, systems can act as sending systems, receiving systems,

or spillover systems; (2) ES flows contain information, materials, and energy and transferred as a result of actions taken by agents [11]; (3) ES agents including ES entities that directly or indirectly facilitate or hinder tele couplings; (4) the reasons behind the occurrence and change of tele couplings; and (5) effects refer to socioeconomic benefits and the ES consequences or impacts of tele couplings (Figure 1). The tele coupling framework has been applied to issues such as urban water systems [15], energy sustainability [16], "Belt and Road Initiative" in China [17], ecosystem services in China's water transfers over large distances [6].

In Figure 1, we develop a conceptual model for applying the tele coupling framework that was built on the basis of TEEB's pathway [18] from ecosystem structure and processes to human well-being diagram. We attempt to define the link between socioeconomic benefits and ES in the tele coupling framework.

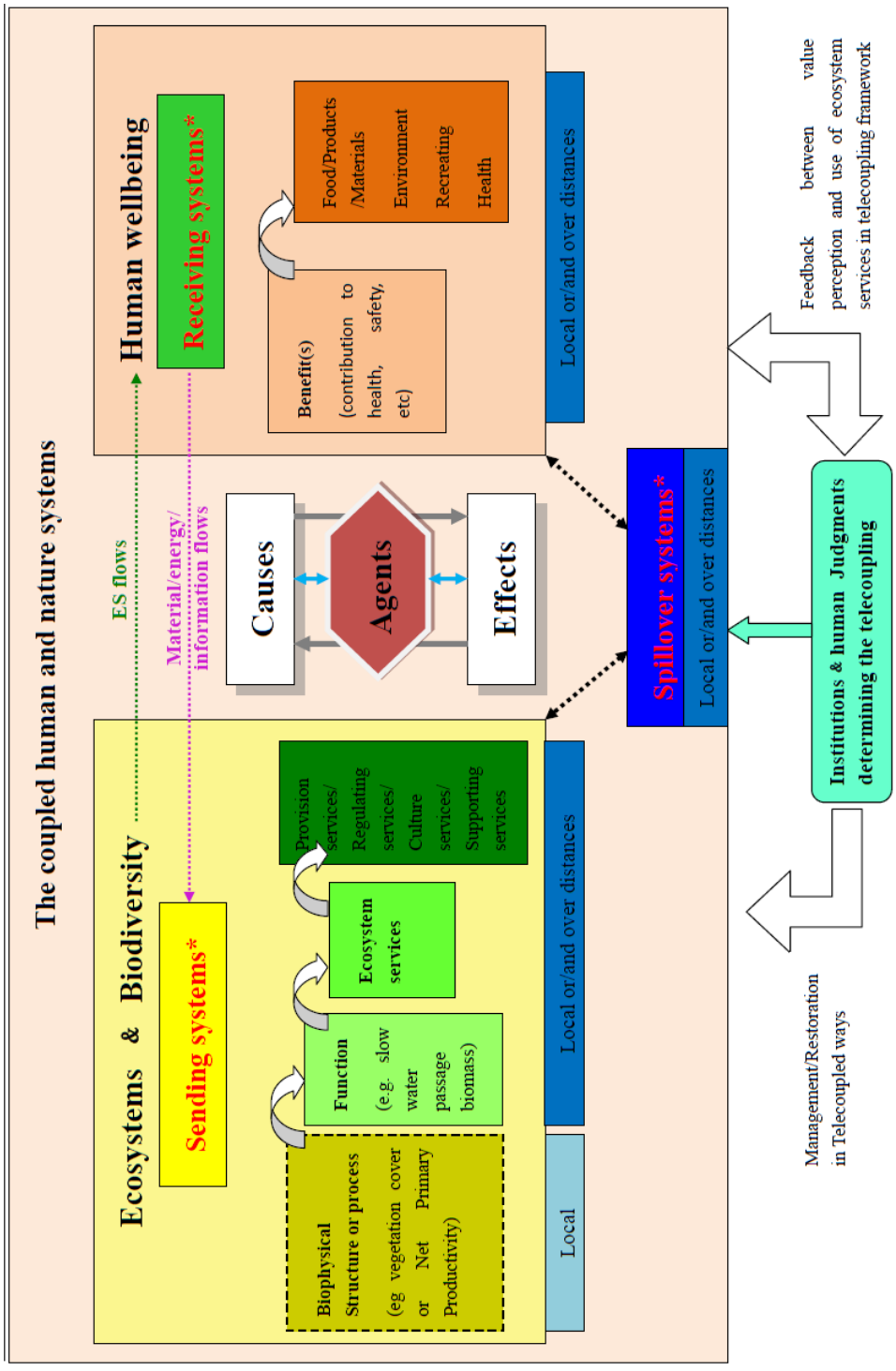

Figure 1. Framing ES in a tele coupling context

In the coupled human and natural system, the Ecosystems & Biodiversity and Human well-being interact with each other through ES flows and material, energy, information flows. Flows are depicted with dashed arrows that indicate the direction of these influences. A “sending” system provides ES to a “receiving” system and influences another “spillover” system in the process. Behind each component is a blue box that express the processes and impact ranges of “local or/and over distances,” e.g., the biophysical structure or process based on the local environment occur locally, but the function and ES can also impact over a larger distance.

It is a conceptual framework for the sake of simplicity; the true situations are more complex.

*The sending/receiving/spillover system can also act as the other one or two systems, depending on the directional movement of the flow considered [11].

2.2 Case study area: Yunnan, China

We choose Xishuangbanna Dai Autonomous Prefecture as the research area, which was an ideal location for developing this tele coupling framework because of the area’s typical tropical ecosystems in the face of socioeconomic benefits.

Xishuangbanna is located in the southwest of China, southwest of Yunnan Province. It is bordered by Burma, Laos, and Vietnam and lies at 99°55′–101°50′E and 21°10′–22°40′N. It has an area of 19124.5 km^2. It is one of the major tropical forest wildness areas in China and in the world, which typically has high biodiversity, has high academic value, and is more vulnerable. Additionally, Xishuangbanna is a global biodiversity hotspot within the scope of Norman Myers’ hotspot areas [19]; thus, the research of tele coupling in this area would be more typical and meaningful.

Tropical deforestation, while slowing in several countries, continues at a high rate. Aside from tropical deforestation, with the development of planting towards simplification trend, Xishuangbanna’s rubber expansion of acreage has jeopardized the original biodiversity and this trend has attracted worldwide attention. This location that borders two countries as well as the nearby Southeast Asian nations is the perfect area for tele couplings.

3. Results

The ES are made up of four different services: provisioning services (e.g., wild foods, crops, fresh water, and plant-derived medicines), regulating services (e.g., carbon storage and water cycling, pollination, and protection from disasters), cultural services (e.g., recreation, spiritual and aesthetic values, and education), and supporting services (e.g., soil formation, photosynthesis, and nutrient cycling) [20].

The assessment of gross ecosystem products does not contain supporting services because these services support the provisioning services and regulating services instead of directly contributing to human well-being. These services are reflected in provisioning services and regulating services [21].

We built the tele coupling framework in Xishuangbanna’s ES, which are tele coupling in provisioning services systems, regulating services systems, and cultural services systems.

3.1 Tele coupling in Provisioning Services Systems (PSS)

The provision services are systems that provide food, materials, water, etc., for society and the economy. In Xishuangbanna, there are tropical products, such as rubber, besides the products mentioned above.

The application of the tele coupling framework in PSS comprises five components: systems, flows, agents, causes, and effects. In systems, there are three types: sending systems, receiving systems, and spillover systems (Table 1).

The sending system of the PSS is Xishuangbanna, itself, and the PSS ecosystem services originate from local ecosystem services. There are rich product resources based on previous climate conditions and geographic locations, such as forest products (wood, rubber, tea, etc.), agricultural products (rice, tropical fruit, etc.), and water resources. Since the 1970s, Xishuangbanna has lost almost 30% of its original forest cover, which has largely been replaced by rubber plantations 22. The rubber outcomes

of materials and products represent a large proportion of forest products. The gross annual value of agricultural outputs has accounted for 45.4% of the gross domestic product in 2015 in Xishuangbanna. In addition, Xishuangbanna is rich in water resources because of the Lancang River Second running through the territory and an abundant amount of rainfall.

The receiving systems of PSS that are more complex consist of Xishuangbanna, Yunnan province, China, Southeast Asian countries, and other countries. This raises important questions about the definition of biodiversity in light of the replacement.

Although sending and receiving systems were matters of concern, the spillover systems that have been previously ignored particularly affected and were affected by the ES. The spillover systems include transport channels, local consumption, factory waste, etc.

Flows occur via movements of material, energy, or information between the systems11. Flows reach the systems in provision services via money, products, people, and transport. Agents are actors that contain producers, governments, sellers, manufacturers, and users in PSS. The causes are demands for rubber, food, and materials, the need for economic development, the technical progress of the producer, abundant resources, and minority cultures. Effects refer to consequences have two sides: the positive and negative effects. In PSS, positive effects are the increase in income, employment, investment, and taxes, the development of social economy sustainability, etc. Negative effects are resource consumption, pollutants, and greenhouse gas emissions in the processing and damage of environmental sustainability.

Table 1. Telecoupling in PSS

Telecoupling in PSS		
Systems	Sending systems	Xishuangbanna
	Receiving systems	Yunnan province, China, southeast Asian countries, other countries
	Spillover systems	Transport channel, consumed locally, factory waste
Flows		Money, products, people, transportation
Agents		Producers, governments, sellers, manufacturers, users
Causes		The demand for rubber, food, and materials; the need for economic development; the technical progress of the producer; abundant resources; minority cultures
Effects	Positive	The increase in income, employment, investment, and taxes; the development of social economy sustainability
	Negative	Resource consumption (land, water, and labor); pollutants and greenhouse gas emissions in processing; damage in environmental sustainability

3.2 Telecoupling in Regulating services Systems (RSS)

The RSS work through indirect services such as water conservation, soil conservation, protective functions, carbon sequestration, waste disposal, etc. They are not direct services, but instead have important roles for the well-being of humans. The components of RSS that contain forests, water, soil, animals, microbes, etc., provide all the contributions.

However, in RSS, the most important contributor is forests, especially tropical forests. Xishuangbanna has 15166 km^2 of forest area that comprises 79.30% of its territory. Of this area, 466.667 km^2 is covered by tropical, primeval forest [23]. The primary forest vegetation here can be categorized into seven main vegetation types and thirty-two formations: tropical rainforest, tropical seasonal moist forest, tropical monsoon forest, tropical lower montane evergreen broad-leaved forest, tropical palm forest, tropical coniferous forest and bamboo forest [24] (Table 2).

A large portion of the value of tropical forests arises from so-called regulating services such as carbon storage, erosion prevention, pollution control, and water purification [25]. In many valuation

studies, these regulating services account for about two-thirds of the total economic value. In contrast, the supply of food, timber, genetic materials, and other materials typically accounts for a relatively small share of the forest's value, although these are the benefits on which perceptions of the economic importance of forests are often based [25].

The benefits of protecting tropical forest ecosystems often outweigh the costs [25], and forest conservation is beneficial for humans, but the question remains: is the RSS not only influential on the local area, but also on the larger area, or possibly the whole world? This is related to tele coupling in RSS.

The sending systems are local ecosystems, especially the forest ecosystem, but the receiving systems are not only in Xishuangbanna, but also in the Yunnan province, China, nearby countries, and the entire world. The spillover systems are spread corridor, reservoirs, etc. All the systems interact by flows that contain water, building materials, biotic organisms, people, and pollutants and cause the regulation functions. Aside from these regulation effects, it also has negative effects such as pollution, greenhouse gas emissions, and security risks in reservoir construction.

Table 2. Telecoupling in RSS

Telecoupling in RSS		
Systems	Sending systems	Xishuangbanna
	Receiving systems	Yunnan province, China, nearby countries, worldwide
	Spillover systems	Spread corridor, reservoirs
Flows		Water, building materials, biotic organisms, people, pollutants
Agents		Governments, ecosystems
Causes		The law of nature; regulation functions; research on the ES; the need for making the value of nature visible
Effects	Positive	Regulation in water conservation; soil conservation, protective functions, and carbon sequestration
	Negative	Pollutants, greenhouse gas emissions, security risks in reservoir construction

3.3 Telecoupling in Culture Service Systems (CSS)

Xishuangbanna has the attractiveness for those seeking pure, atural, and cultural sights, is becoming increasingly attractive to both domestic and foreign tourists due to its unique geographical location and humane environment. The tourists coming to Xishuangbanna are increasing every year. From 2010 to 2015, the number of domestic and foreign visitors and the tourism revenue have increased rapidly.

During 2015, Xishuangbanna attracted 20.014 million domestic and foreign visitors and had a large increase of about 17.7% more than the previous year. Among them, there were 0.3324 million foreign visitors and foreign exchange earnings from international tourism, which topped 240.76 million US dollars, up 12.3% from last year.

As the tele coupling in ecological culture service systems, the receiving systems are the tourism destination itself and the tourism ventures, e.g., scenic spots, restaurants, and hotels. Sending systems are the places from which the domestic and foreign visitors come, similar to China and all over the world. The spillover systems contain associated infrastructure, e.g., roads, corridors, and reservoirs. All of these come through the flows such as tourists, transport systems (airport, highway, road), and tourism practitioners.

The ecological culture service systems may bolster socioeconomic sustainability, reduce resource consumption, and benefit the environment while being locally absent11. The increase in income, employment, investment, and taxes and the development of social economy sustainability

are additional positive effects. The negative effects might potentially threaten environmental sustainability[11] (Table 3).

Table 3. Telecoupling in CSS

Telecoupling in CSS		
Systems	Sending systems	Yunnan province, China, worldwide
	Receiving systems	Xishuangbanna
	Spillover systems	Spread corridor, reservoirs
Flows		Tourists, transport systems (airport, highway, road), tourism practitioners
Agents		Governments, scenic spots, hotels, restaurants
Causes		The attractions in natural scenery and humanism characteristics; travel demands; government interest and demands for investment and economic development; convenient transportation
Effects	Positive	Bolsters socioeconomic sustainability, reduces resource consumption, and benefits the environment while being absent at home; the increase in income, employment, investment, and taxes; the development of social economy sustainability
	Negative	Potentially threatens environmental sustainability

4. Conclusion and Discussion

It would be wise to apply economic thinking to the utilization of biodiversity and ecosystems like the TEEB project plan. Maintaining stocks of natural capital allow for the sustained provision of the future flow of ecosystem services, and thereby helps to ensure continued human well-being. Economic thinking can help clarify two critical points: why prosperity and poverty reduction depend on maintaining the flow of benefits from ecosystems, and why successful environmental protection needs to be grounded in sound economics [25]. Exposing the value of nature and the link between ES and human socioeconomic benefits is useful for the protection of biodiversity and ES.

These can also help decision-makers create effective policies for development and conservation, which depend on an understanding of the mechanisms underlying environmental sustainability [26].

Nowadays, some local policymakers focus only on the local area, completely overlooking the larger regions' chain reactions and impacts.

Therefore, the tele coupling framework can provide a broader analytical lens with which to integrate distant socioeconomic and environmental interactions that affect sustainability on a local and global scale [11]. The current research surrounding this field is lacking due to increased global interactions over spatial distances. The tele coupling perspective can help to advance ES research and policy and can also change the visual angle of study on ES by placing an emphasis on distance rather than on one place. A brace of policy initiatives suggests that national authorities have become much more focused on a local level or their own country's interactions. The formulation of policy measures which are implementing right now are made without the consideration of distances. Previous research on human-nature feedback focused primarily on individual coupled systems instead of across multiple coupled systems, an improved understanding of cross-system feedbacks represents an important conceptual advance [27]. The tele coupling in ES would aid in the governance of sustainable development and biodiversity protection. Further research of tele coupling on ES might highlight the view of distance between ES and enhance coupled human and nature system in complex global interactions.

However, we also stress that this study has shortcomings with respect to the quantitative research, which is exactly we are solving in the next step.

Acknowledgements

The authors wish to thank our colleagues for their valuable ideas and comments at different stages of this article. Special thanks are extended to Professor Liu Jianguo for his helpful comments and advice. This work was supported by the 2017 Yunnan Provincial Department of Education Science Research Foundation Project (Grant 2017ZZX210).

References

[1] TEEB.2008.The Economics of Ecosystems and Biodiversity: An interim report. http://doc.teebweb.org/wp-content/uploads/Study%20and%20Reports/Additional%20Reports/Interim%20report/TEEB%20Interim%20Report_English. Pdf (accessed 28 March 2017).

[2] Costanza R., Cumberland J.C., et al, 1997. An Introduction to Ecological Economics. St. Lucie Press, Boca Raton, Florida.

[3] MA (Millennium Ecosystem Assessment). 2005. Ecosystems and human well-being: synthesis. Washington, DC: Island Press.

[4] TEEB.2010. The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB. http://www.teebweb.org/TEEBSynthesisReport/tabid/29410/Default.aspx (accessed 12 March 2017).

[5] TEEB.2010. the Economics of Ecosystems and Biodiversity Ecological and Economic Foundations. Edited by Pushpam Kumar. Earthscan, London and Washington. http://www.teebweb.org/our-publications/teeb-study-reports/ecological-and-economic-foundations/#.Ujr1xH9mOG8 (accessed 25 March 2017).

[6] Liu J.G., Yang W., Li S. X. 2016. Framing ecosystem services in the tele coupled Anthropocene, Front Ecol Environ, 14 (1): 27-36. DOI: 10.1002/16-0188.1

[7] Kates, R.W., and Clark, W. C.., Corell R.., et al., 2001.Sustainability science. Science, 292 (5517): 641-642. DOI: 10.1126/science.1059386

[8] Turner B.L., Kasperson R.E., Matson P.A., et al.,2003. A framework for vulnerability analysis in sustainability science. Proceedings of the National Academy of Sciences of the United States of America 100:8074-8079. DOI: 10.1073/pnas.1231335100

[9] Daily G.C., editor. 1997. Nature's services: societal dependence on natural ecosystems. Island Press, Washington, D.C., USA.

[10] Liu J.G., Li S.X., Ouyang Z.Y., et al., 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 105:9477-9482. DOI: 10.1073/pnas.0706436105

[11] Liu J.G., Hull V., Batistella M., et al., 2013. Framing sustainability in a tele coupled world. Ecology and Society 18(2): 26. http://dx.doi.org/10.5751/ES-05873 - 180226

[12] Brauman K.A., Daily G.C, Duarte T.K, Mooney H.A., 2007. The nature and value of ecosystem services: an overview highlighting hydrologic services. Annu RevEnv Resour.32: 67-98. DOI: 10.1146/annurev.energy.32.031306.102758

[13] Burkhard B., Kroll F., Nedkov S., Muller F., 2012. Mapping ecosystem service supply, demand and budgets. Ecol Indic, 21: 17-29. DOI: 10.1016/j.ecolind.2011.06.019

[14] Liu J.G, Dietz T., Carpenter S.R., et al., 2007. Coupled human and natural systems. Ambio, 36 (8): 639-649. DOI: 10.1579/0044-7447(2007)36[639: CHANS]2.0.CO;2

[15] Jillian M. Deines, Xiao Liu, Liu J.G. 2015. Telecoupling in urban water systems: an

examination of Beijing's imported water supply, Water International, 1-16.DOI: 10.1080/02508060.2015.1113485

[16] Fang B.L., Tan Y., Li, C.B., et al., 2016. Energy sustainability under the framework of tele coupling. Energy, 106: 253-259. DOI: 10.1016/j.energy.2016.03.055

[17] Yang D., Cai J., Hull V., et al., 2016. New road for tele coupling global prosperity and ecological sustainability. Ecosystem Health and Sustainability, 2 (10): 1-6. DOI: 10.1002/ehs2.1242

[18] TEEB. 2011. The Economics of Ecosystems and Biodiversity in National and International Policy Making. Edited by Patrick ten Brink. Earthscan, London and Washington. http://www.teebweb.org/our-publications/teeb-study-reports/national-and-international-policy-making/#.Ujr14n9mOG8 (accessed 12 March 2017).

[19] Myers N., Mittermeier R.A., Mittermeier C.G., et al., 2000. Biodiversity hotspots for conservation priorities. Nature, 403 (6772): 853 - 858. DOI: 10.1038/35002501.

[20] TEEB. 2012. The Economics of Ecosystems and Biodiversity in Local and Regional Policy and Management. Edited by Heidi Wittmer and Haripriya Gundimeda. Earthscan, London and Washington.http://www.teebweb.org/our-publications/teeb-study-reports/local-and-regional-policy-makers/#.Ujr1939mOG8 (accessed 29 March 2017).

[21] Ouyang Z.Y., Zhu C.Q., and Yang G.B., et al., Gross ecosystem product: concept, accounting framework and case study. Acta Ecologica Sinica, 2013, 33 (21): 6747 - 6761.

[22] Zhang J.Q., Sun Joseph Chang, Alison Wee, et al., 2015. Study on economic compensation standard for the conversion of rubber plantation to rainforest in Mandan Village, Xishuangbanna, Resources Science, 37 (12): 2461 - 2470.

[23] Xishuangbanna government affairs network, 2016-11-2. Http: //www.xsbn.gov.cn/88.news.detail.dhtml?news_id=34206 (accessed 27 March 2017).

[24] Zhu H., Wang H., Li B.G., et al., 2015. Studies on the Forest Vegetation of Xishuangbana. Plant Science Journal, 2015, 33 (5): 641 - 726.

[25] TEEB.2010. Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB. Earthscan, London and Washington, http://www.teebweb.org/our-publications/teeb-study-reports/synthesis-report/#.Ujr2cX9mOG8 (accessed 28 March 2017).

[26] Foley J.A., Asner G.P., Costa M.H., et al., 2007. Amazonia revealed: forest degradation and loss of ecosystem goods and services in the Amazion Basin. Front Ecol Environ, 5: 25-32. DOI: 10.1890/1540-9295 (2007)5 [25: ARFDAL]2.0.CO;2

[27] Hull V., Tuanmu M.N., Liu J.G., 2015. Synthesis of human-nature feedbacks. Ecology and Society, 20: 17. DOI: 10.5751/ES-07404 - 200317.