Do not judge a book by its cover: ecosystem service of the Kaomei wetland

Lee, Huey-Lin[1]
Lin, Hsin-Juh[2]

Abstract:

In this study we attempted to illustrate a way of linking the value of ecosystem services with the economy and thus revealing the economic significance of ecosystem service which has long been overlooked in human economic activities. We chose as the study object the Kaomei Wetland in Central Taiwan—which is rated as 'wetland of national importance', based on the Ramsar Convention treaties. We first conducted field survey and experiments to identify the Kaomei Wetland as a land use type of low landscape development intensity (LDI) and assessed the latent economic value of the ecosystem services Kaomei Wetland provides, based on the conceptual framework as proposed by the TEEB. We then incorporated the latent economic value—in the form of "avoided cost" and "replacement cost" as implied by the Kaomei ecosystem services while maintaining it as a low LDI land use type—to a bottom-up multi-regional computable general equilibrium (CGE) model of Taiwan to see how far-reaching the avoided/replaced costs, if spared for other non-wastewater treatment use, could alternatively affect the economy of the local and other domestic regions through inter-region linkage and the input-output relationship in the production and consumption processes. We aim to demonstrate the significant economic contribution of the seemingly low-economic-value land use type like the Kaomei Wetland could potentially make to the human wellbeing in the perspective of economics.

Keywords: multi-regional computable general equilibrium, ecosystem services, wastewater treatment, replacement cost, avoided cost.

1 Associate Professor, Dept. of Economics, National Chengchi University, Taipei, Taiwan. Email: hlee@mail2.nccu.tw

2 Professor, Dept. of Life Sciences, National Chung-Hsing University, Taichung, Taiwan.

1. Introduction

Through the provision of ecosystem services, wetlands have long been supporting the human economy without receiving due appreciation, let alone monetary compensation. Studies in recent environmental economics literature has seen increased interest in the valuation of ecosystem service, which, as defined in Costanza et al. (1997), refers to the benefits human populations derive directly or indirectly from ecosystem functions. Table 1 tallies the contribution of wetland ecosystem service, as indicated in the TEEB (2010) and Millennium Ecosystem Assessment (2005).

In ecological engineering practices, ecosystem services offered by nature as well as constructed wetlands have been popularly accepted and utilized for wastewater treatment, which allow for reduction in the use of non-renewable inputs for wastewater treatment. Although latent, economic value of the wetland is of significance to economic well-being of human societies. Humans have long been utilizing the ecosystem services provided by wetlands, yet at the same time disrupting the ecosystem in day-to-day economic activities.

According to Geber and Bjorklund (2002), ecosystem services used in wastewater treatment consist of three broad ecological functions: (a) biological: denitrification, nitrification, fermentation, plant uptake, and oxidization of organic matter; (b) chemical processes: ammonification, adsorption, and fixation; (c) physical: sedimentation, evaporation, and transpiration. Geber and Bjorklund (2002) used emergy analysis to investigate the substitutablility of increased use of space (land area), time and dependence on ecosystem services for purchased non-renewable inputs in wastewater treatment in Sweden—of three types: (1) conventional three-step treatment plant (WWTP), (2) conventional mechanical /chemical treatment plant complemented with a constructed wetland (TP+CW), and (3) natural wetland (NW). Geber and Bjorklund (2002) found that total use of emergy per person equivalent and kg phosphorus was undifferentiated, and the emergy ratios of purchased to free renewable environmental inputs are 9:1, 141:1, and 3056:1, for NW, TP+CW, and WWTP, respectively. This study indicates the environmental efficiency of both natural and constructed wetlands in serving for wastewater treatment.

Bateman et al. (2011) reports the comprehensive study conducted for the UK case, and identified ecosystem services and corresponding goods (see Table 2). Bateman et al. (2011) also reviewed preceding literature and thereby proposed a general framework (see Figure 1) and nomenclature for integrating economic analyses within ecosystem service assessment. A comprehensive summary of valuation methods being applied to ecosystem services was provided in Bateman et al. (2011) – see Table 3. To our best knowledge of the literature, there has not yet seen any research applying Computable General Equilibrium (CGE), nor Input-Output Analysis (IOA), for valuation of ecosystem service, particularly on the replacement cost.

We attempted to use a general equilibrium economic model as an alternative approach to finding the economic value of ecosystem service being provided by the less human-disturbed Kaomei coastal wetland in central Taiwan.

In this study, we based on the idea as inspired by Leontief (1970) as well as the "broken window fallacy" to propose an approach of measuring the replacement cost as provided by the ecosystem service. In the subsequent sections, we first introduce in section 2 the case studied, the Kaomei coastal wetland, located in central Taiwan; section 3 introduces the inspiring ideas we derived from the "Broken Window Fallacy" and Leontief (1970); section 4 describes the multi-region computable general equilibrium model; we show in section 5 some key results of the CGE assessment of the replacement cost offered from the ecosystem service, section 6 concludes the report.

Table 1. Contribution of the wetlands' ecosystem service towards sustainable development

Economy	Society	Environment	
Provisioning	**Cultural**	**Regulating**	**Habitat**
Agriculture	Recreation and tourism	Flood control	Supporting external ecosystem
Fishery	Aesthetic values	Storm surge control	Nutrient cycling
Forestry	Academic advancement	Groundwater recharge	Primary production
Hunting	Environmental education	Climate regulation	Soil formation
Transport	Cultural heritage	Coastline protection	biodiversity
Fiber and fuel	Social capital	Water filtration/purification	
Genetic diversity		Pollination	
Pharmaceuticals		Carbon storage	

Source of table: drew upon TEEB (2010) and MA(2005).

Table 2. Final ecosystem services and corresponding goods: Examples from the UK NEA

Final ecosystem service[a]	Principal related goods
Production of crops, plants, livestock, fish, etc. (wild and domesticated)[b]	Food, fibre, energy, genetic resources, industrial inputs, fertiliser, avoidance of climate stress, recreation and tourism, physical and mental health, ecological knowledge, etc.
Production of trees, standing vegetation and peat[b]	Timber, avoidance of climate stress, energy, noise regulation, recreation and tourism, etc.
Production of wild species diversity including microbes[b, c]	Natural medicine, disease and pest control, genetic resources, wild food, bioprospecting, recreation and tourism, physical health, ecological knowledge, etc.
Production of water quantity[b, c]	Potable water, Industrial use of water, flood protection, energy, recreation and tourism, physical health, ecological knowledge, etc.
Regulation of the climate[c]	Avoidance of climate stress, physical and mental health, ecological knowledge, etc.
Regulation of hazards; related vegetation and other habitats[c]	Coastal protection, erosion protection, flood protection, avoidance of climate stress, physical and mental health, ecological knowledge, etc.
Breakdown and detoxification of waste[c]	Pollution control, waste removal, waste degradation, physical and mental health, ecological knowledge, etc.
Purification processes[c]	Clean air, clean water, clean soils, physical health, ecological knowledge, etc.
Generation and maintenance of meaningful places; socially valued landscapes and waterscapes[d]	Recreation and tourism, physical and mental health, ecological knowledge, etc.

[a] As noted previously, other inputs (e.g. manufactured capital) may in some occasions be required to combine with final ecosystem services in the production of goods. Relating the final ecosystem services to the MA (2005) nomenclature:

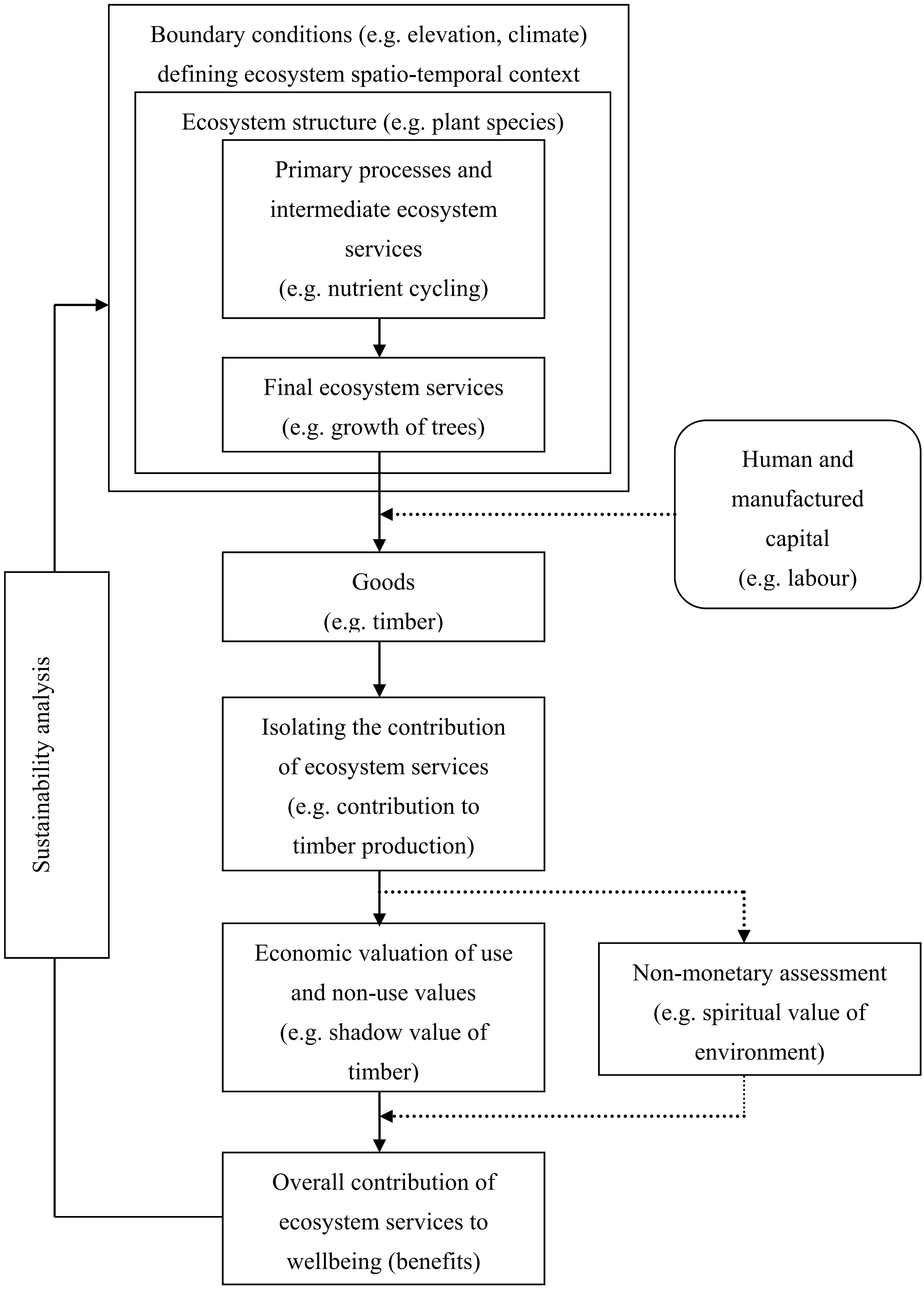
[b] 'Provisioning' services;

[c] 'Regulating' services;

[d] 'Cultural' services. 'Supporting' services relate to primary ecological services

Source: Bateman et al. (2011).

Figure 1. Phases of a joint ecosystem assessment and economic analysis for a single scenario



Source: Bateman et al. (2011).

Notes: (a) Examples given in parentheses; (b) solid lines indicate relations which always apply while dotted lines indicate relations.

Table 3. Various valuation methods applied to ecosystem services

Valuation method	Value types	Overview of method	Common types of applications	Examples of ecosystem services valued	Example studies
Adjusted market prices	Use	Market prices adjusted for distortions such as taxes, subsidies and non-competitive practices.	Food, forest products, R&D benefits.	Crops, livestock, multi-purpose woodland, etc.	Bateman et al. (2003), Godoy et al. (1993)
Production function methods	Use	Estimation of production functions to isolate the effect of ecosystem services as inputs to the production process.	Environmental impacts on economic activities and livelihoods, including damage costs avoided, due to ecological regulatory and habitat functions	Maintenance of beneficial species; maintenance of arable land and agricultural productivity; support for aquaculture; prevention of damage from erosion and siltation; groundwater recharge; drainage and natural irrigation; storm protection; flood mitigation	Ellis and Fisher (1987), Barbier (2007).
Damage cost avoided	Use	Calculates the costs which are avoided by not allowing ecosystem services to degrade.	Storm damage; supplies of clean water; climate change.	Drainage and natural irrigation; storm protection; flood mitigation	Badola and Hussain (2005), Kim and Dixon (1986).
Averting behaviour	Use	Examination of expenditures to avoid damage	Environmental impacts on human health	Pollution control and detoxification	Rosado et al. (2000).

Table 3 (continued)

Valuation method	Value types	Overview of method	Common types of applications	Examples of ecosystem services valued	Example studies
Revealed preference methods	Use	Examine the expenditure made on ecosystem related goods (e.g. travel costs; property prices in low pollution areas).	Recreation; environmental impacts on residential property and human health.	Maintenance of beneficial species, productive ecosystems and biodiversity; storm protection; flood mitigation; air quality, peace and quiet, workplace risk.	See Bockstael and McConnell (2006) for the travel cost method and Day et al. (2007) for hedonic pricing.
Stated preference methods	Use and non-use	Uses surveys to ask individuals to make choices between different levels of environmental goods at different prices to reveal their willingness to pay for those goods	Recreation; environmental quality, impacts on human health, conservation benefits.	Water quality, species conservation, flood prevention, air quality, peace and quiet.	See Carson et al. (2003) for contingent valuation and Adamowicz et al. (1994) for discrete choice experiment approach.

Source: Bateman et al. (2011)–adapted from de Groot et al. (2002), Heal et al. (2005), Barbier (2007), Bateman (2009) and Kaval (2010).

2. Case studied: Kaomei wetland

Kaomei wetland, taking up 701.3 ha and 3.5km stretch of coastline in central Taiwan, used to be a beach resort prior to the construction of the Taichung Harbor in 1976—which caused piling up of floating sands. Albeit losing swimmer visits afterwards, Kaomei became a paradise for wild creatures and migratory birds. As shown in Figure 2, Kaomei wetland is rich in biodiversity, with the endangered Platalea minor and various varieties of grass—including Bolboschoenus planiculmis (F.Schmidt) T. Koyama (雲林莞草), Hygrophila pogonocalyx (大安水蓑衣), Platalea minor (黑面琵鷺), Mudskipper (彈塗魚), Kandelia mangrove (水筆仔), Beckoning crab (招潮蟹). In September 2004, the state Council of Agriculture officially declared the Kaomei wetland as a site for wildlife conservation.

Kaomei wetland, by its face, does not look of high economic value. From the ecological perspective, it has quite low human disturbance, which helps maintaining the rich biodiversity. For the perspective of economic development, an area of such low economic profile tends to be converted into built-up land for better economic payoff. However, with increasing awareness of and appreciation for ecosystem service, local ecologists contended with economic planners for conserving the Kaomei biodiversity by keeping Kaomei wetland as it is, rather than surrendering to industrial/commercial use for better economic payoff.

In this study, we attempted to give a value—based on the replacement cost method as suggested in the TEEB for the ecosystem service of water purification function—for keeping the seeming economically marginal yet low-LDI Kaomei wetland. We employed a multi-regional computable general equilibrium model (MR-CGE) of Taiwan to do the assessment and come up with an "extended" replacement cost estimate for the Kaomei wetland, as opposed to the conventional ecological engineering estimation.

Lin et al. (2011) identified the degree of human influence on the Kaomei wetland using the landscape development intensity (LDI) index, which is proposed by Brown and Vivas (2005). The scope of LDI index calculation for the Kaomei wetland is shown in Figure 3. Based on emergy of human activities in a certain size of area during a certain period of time, covering consumption of electricity, coal, fertilizer, pesticide, tap water, and irrigation water, the LDI measures the degree of human disturbance to the wetland ecosystem. The formula for calculating LDI is as follows:

$$LDI_{total} = \Sigma_i (\%LU_i \times LDI_i), \text{ i for all land use types,}$$
(Eq. 1)

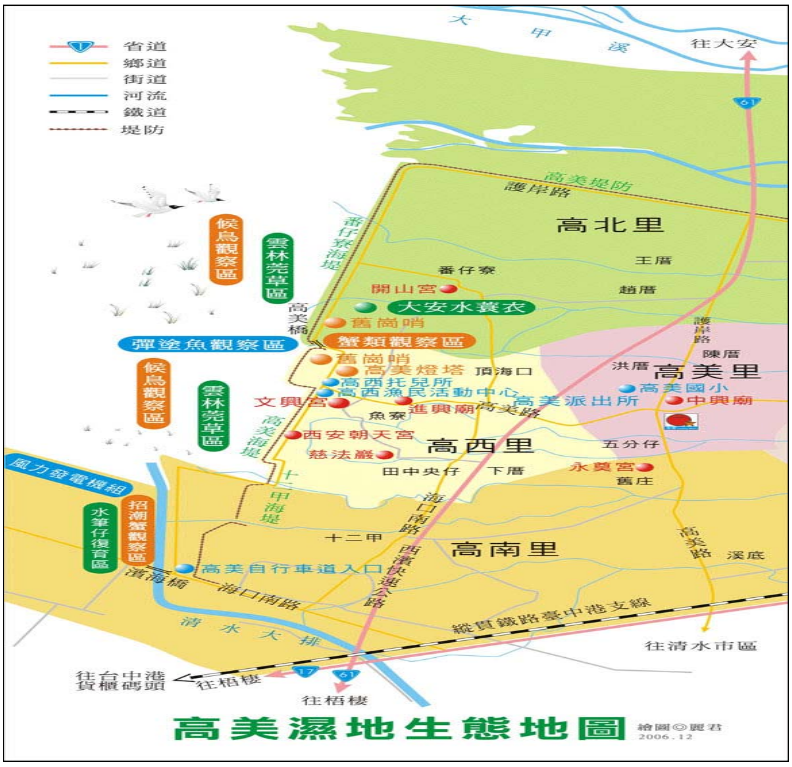
where LUi denotes the area of the land use type i;

LDIi denotes the land development intensity coefficient of the land use type i.

Lin et al.(2011) used the National Land Use Survey Data (see Figure 4) for the variable LUi of Eq. 1, and the LDIi information (see Table 4) is borrowed from Brown and Vivas (2005) for the Florida case study—as so far there is not yet estimation of the land development intensity parameter for the Taiwan case. The LDI index for Kaomei wetland is calculated as 1.80, which indicates a rather low human disturbance. This corresponds with the official ranking made based on the criteria of 50% weighing of species richness (biodiversity) across Taiwan's 74 wetland sites of significance (Chen and Lin, 2011), among which Kaomei wetland ranked 7th.

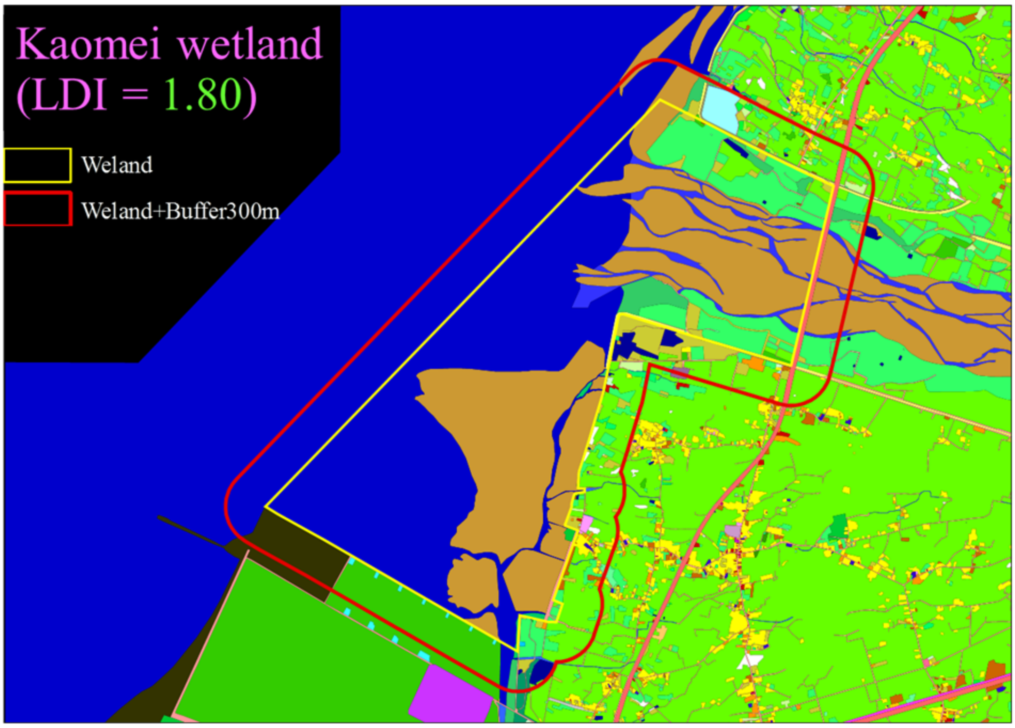
Lin et al.(2011) also assessed the values of various ecosystem services provided by the Kaomei wetland. Tables 5a - 5c tally the estimated values of the ecosystem services, among which we picked the ecosystem service of water purification to demonstrate an alternative approach to giving a value for the ecosystem service. The ecosystem service value of water purification was measured by the replacement cost—that is, the cost of building a conventional wastewater treatment plant of same processing capacity of the Kaomei wetland—which amounts to 10,900 million Taiwan dollars (see Table 5b).

Figure 2. Biodiversity map of the Kaomei wetland



Source: http://www.gaomei.com.tw/wetland_map.php

Figure 3. Scope of LDI index calculation for the Kaomei wetland



Source: Lin et al. (2011).

Figure 4. Land use classification of the National Land Use Survey data of Taiwan

Source: Wang (2007).

Table 4. Categories of the Florida land-use classification system and their LDI coefficients

Land use	LDI coefficients
Natural system	1.00
Natural open water	1.00
Pine plantation	1.58
Recreational/open space (low intensity)	1.83
Woodland pasture (with livestock)	2.02
Pasture (without livestock)	2.77
Low intensity pasture (with livestock)	3.41
Citrus	3.68
High intensity pasture (with livestock)	3.74
Row crops	4.54
Single family residential (low density)	6.90
Recreational/open space (high intensity)	6.92
High intensity agriculture (dairy farm)	7.00
Single family residential (medium density)	7.47
Single family residential (high density)	7.55
Mobile home (medium density)	7.70
Highway (2 lane)	7.81
Low intensity commercial	8.00
Institutional	8.07
Highway (4 lane)	8.28
Mobile home (high density)	8.29
Industrial	8.32
Multi-family residential (low rise)	8.66
High intensity commercial	9.18
Multi-family residential (high rise)	9.19
Central business district (average 2 stories)	9.42
Central business district (average 4 stories)	10.00

Source: Brown and Vivas (2005).

Table 5a. Estimated value of ecosystem service of the Kaomei wetland

Kaomei coastal wetland			Survey methods		Significance of survey			Equivalent value
Low human disturbance								
LDI = 1.80			Price	Value	H	M	L	
Economy	Provisioning	Agriculture	Market price				v	
		Fishery	Market price			v		0.92 mil
		Forestry	Market price				v	
		Hunting	Market price				v	
		Transport	Market price				v	
		Fiber and fuel	Market price				v	
		Genetic diversity	Market price		v			?
		Pharmaceuticals	Market price				v	

Source: Lin et al. (2011).

Table 5b. Estimated value of ecosystem service of the Kaomei wetland

Kaomei coastal wetland Low human disturbance			Survey methods		Significance of survey			Equivalent value
LDI = 1.80			Price	Value	H	M	L	
Environment	Regulating	Flood control	Mitigation/ Replacement cost				v	
		Storm surge control	Mitigation/ Replacement cost		v			
		Groundwater recharge	Mitigation/ Replacement cost				v	
		Climate regulation	Mitigation/ Replacement cost			v		306.72 mil
		Coastline protection	Mitigation/ Replacement cost		v			300 mil
		Water filtration/ purification	Mitigation/ Replacement cost			v		10,900 mil
		Hydrological cycle	Mitigation/ Replacement cost				v	
		Pollination	Market price				v	
		Carbon storage	Mitigation/ Replacement cost			v		0.19 mil

Table 5c. Estimated value of ecosystem service of the Kaomei wetland

Kaomei coastal wetland Low human disturbance			Survey methods		Significance of survey			Equivalent value
LDI = 1.80			Price	Value	H	M	L	
Environment	Habitat	Supporting external ecosystem	Replacement cost/ CV		v			414.97mil
		Nutrient cycling	Replacement cost			v		10,900mil
		Primary production	Replacement cost		v			601.81mil
		Soil formation	Replacement cost				v	
		biodiversity	Replacement /mitigation cost		v			349mil

3. The inspiring ideas in "Broken Window Fallacy" and Leontief (1970)

3.1 The "Broken Window Fallacy" (BWF)

Frédéric Bastiat (1850) essay titled as Ce qu'on voit et ce qu'on ne voit pas (That Which Is Seen and That Which Is Unseen) pointed out the opportunity cost of the broken window. The center piece question is: would it help with economic growth by breaking a window of the bakery?

What is seen is that glazier gains business as the bakery shopkeeper had to order for window repair; glass producer thus gain business order from the glazier; the input supplier to the glass producer in turn gains business as such; and so on. As the chain effect goes on and on for numerous runs, and affect various inter-linked sectors, GDP will go up, and employment increases of these positively affected sectors as well.

On the other hand, what is not seen is that shopkeeper loses money to window repair, which he would otherwise spend on a new pair of shoes; shoemaker thus loses business from the shopkeeper; the input supplier to the shoemaker in turn loss business as such; and so on. As the chain effect goes on and on for numerous runs, and affect various inter-linked sectors, GDP will go down, employment of these adversely affected sectors declines as well. In the end, the net benefit of a chain repercussions due to the broken window would not be enough to compensate the lost worth of the bakery's broken window.

The chain repercussions indicated in the BWF correspond with those in the Input-Output Analysis as developed by Leontief (1986). Leontief (1970) proposed a way of applying the Input-Output Analysis to environmental issues—in particular, pollution. We introduced the key ideas and inspiration we derived from Leontief (1970).

3.2 Key ideas derived from Leontief (1970)

Leontief (1970) addressed environmental repercussions within the economic structure with the Input-Output Approach he developed. The key conclusion revealed in Leontief (1970) is that there is a price (or cost) for environmental quality (as a good).

Leontief (1970) assumed that pollution cleaning took produced goods as inputs, e.g., fabric and labor. Based on the Input-Output analysis, requirement for pollution elimination—that is, better environmental quality—ended up raising GDP, while real consumption remained constant. More demand for cleanness, more fabric and labor needed, which in turn pushes up production of fabric, and thus pollution associated with fabric production. The increment in GDP (induced by the clean-up activities) turned out to be the payment for pollution elimination, as real consumption remains the same. That is, the gap between GDP and real consumption is the total cost of pollution elimination efforts (or cost of having certain level of environmental quality), defrayed by the final consumers, directly or indirectly.

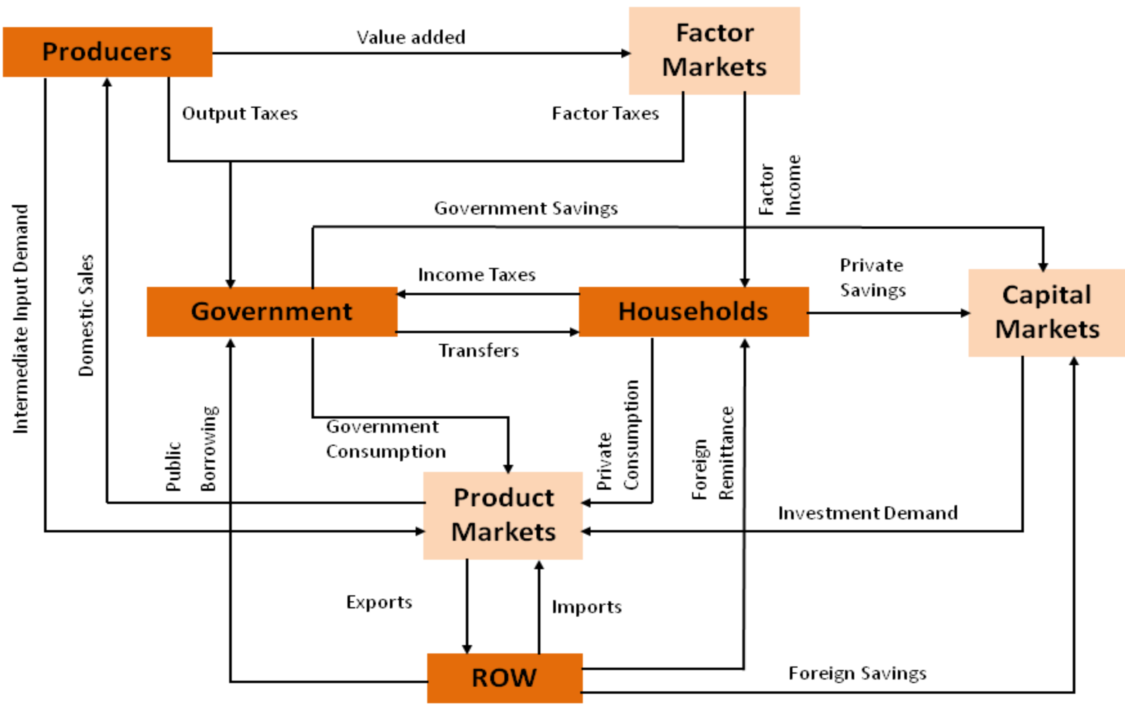
Kaomei wetland plays a role similar to the window in the BWF. What is even more benevolent is that Kaomei wetland has been offering the environmental quality, yet free of charge. As we narrated previously, both Bastiat's (1850) BWF and Leontief (1970) used the concept of inter-sector linkage through input-output demand/supply relationship. This coincidence prompted us to further pursuit an alternative way of assessing ecosystem services. We hope this could offer a new perspective whenever the pursuit of environmental sustainability has to contend with the economic prosperity. In this study we attempted to find the "replacement cost" as in TEEB (2010) and in Boyer and Polasky (2004), yet "extended", by using an input-output based multi-regional computable general equilibrium (MR-CGE) model of the Taiwan economy. We believe this alternative approach to measuring the "extended" replacement cost commensurate with the value of the ecosystem services provided by wetlands adds upon the literature by revealing the society's total "opportunity cost" of losing Kaomei wetland's ecosystem services.

4. A multi-region computable general equilibrium model

We constructed a multi-regional computable general equilibrium model of Taiwan covering four sub-regions of Taiwan: North, Central, South, East, and 52 producing sectors, consumption of private households, government and exports. The MR-CGE model describes the circular flows of the economy (as depicted by Figure 5), behavior of all economic agents (including producers and consumers, domestic and foreign), and the inter-sectoral linkage thru input-output demand and supply relations.

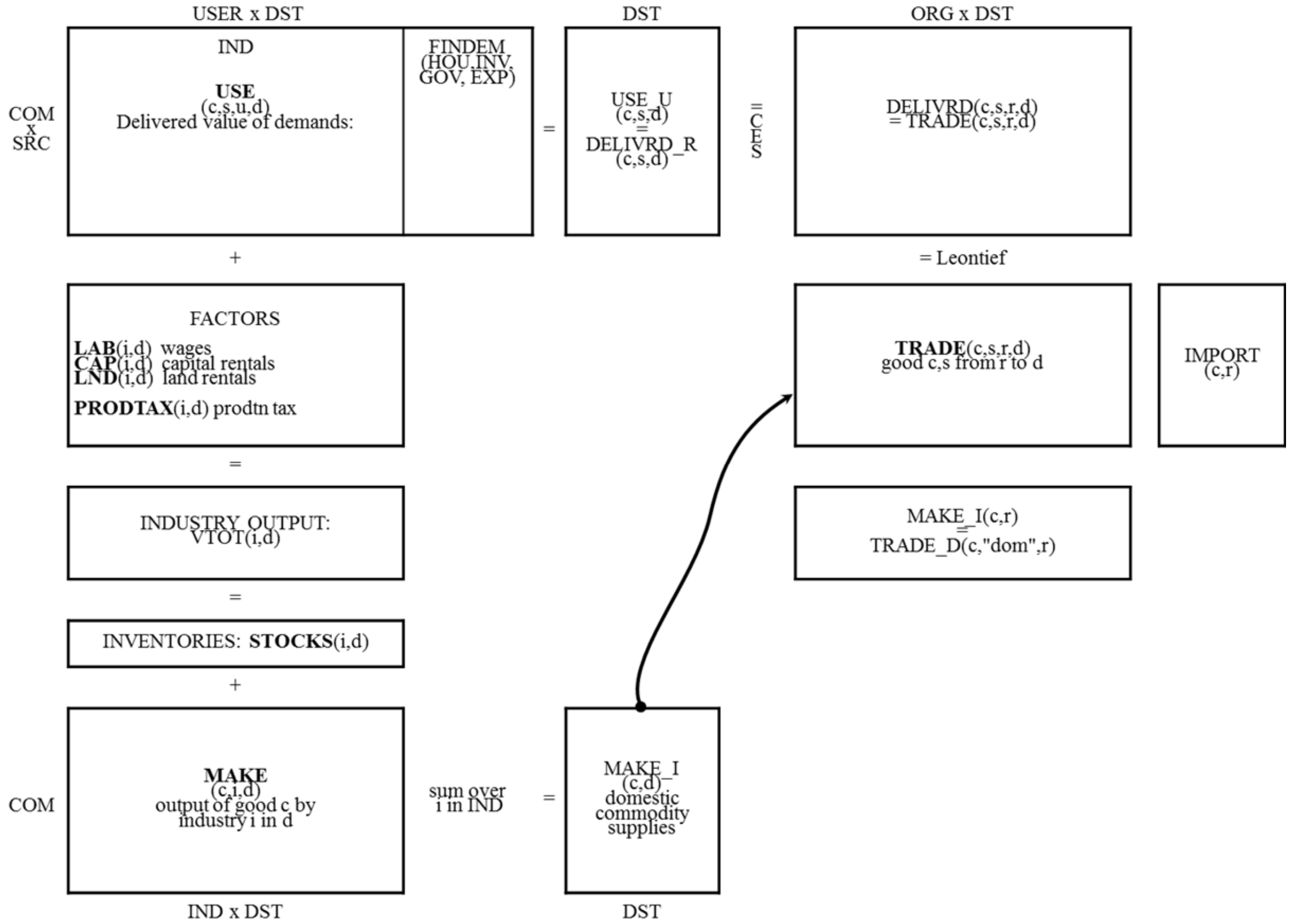
Figure 6 shows the format of the Input-Output and inter-region trade flows data used in the MR-CGE model for benchmarking. Figure 7 shows the production structure specified in the model for the producing industries in a sub-region; Figure 8 shows the final demand structure of consumers. Figure 9 shows the inter-region linkage thru in-flows and out-flows of goods/services. All agents act out the market mechanism of Neoclassic Economics, that is, the model assumes upward-slopping supply curves and downward-slopping demand curves. This is much better assumption for the economic operation as opposed to that in Leontief (1970) Input-Output model, which assumed perfectly elastic supply of resources.

Figure 5. Circular flows in the economy



Source: IADB (2010).

Figure 6. Input-Output accounts and inter-region trade flows data used in the MR-CGE model



Source: Adapted from Horridge et al. (2005).

Figure 7. Production structure of an industry in a region

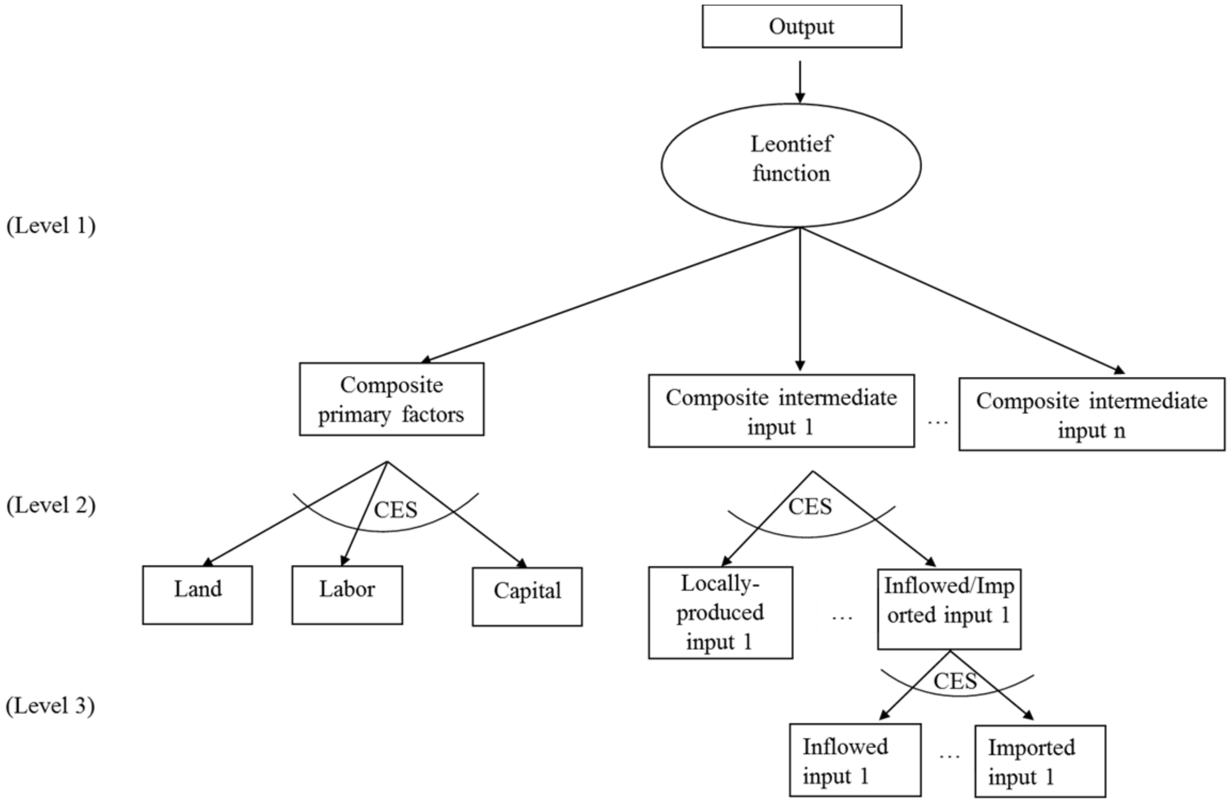


Figure 8. Final demand structure of a region

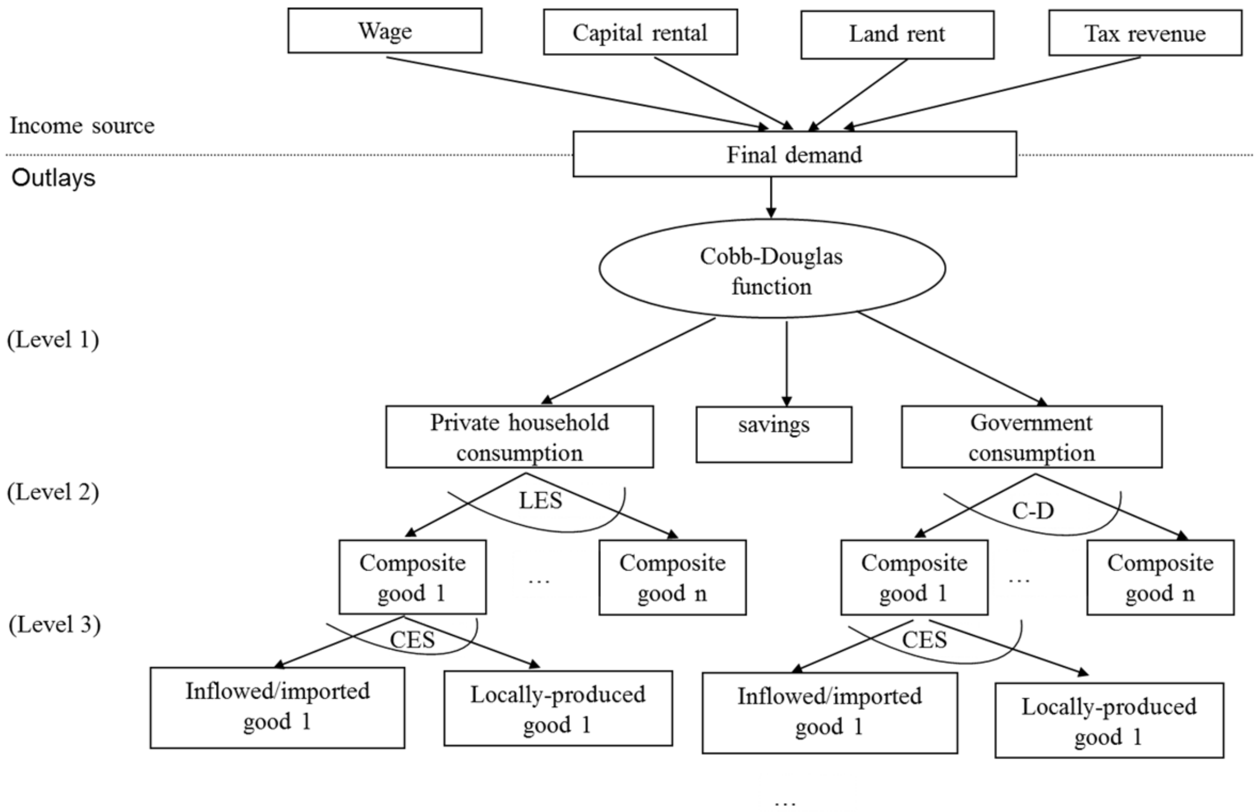
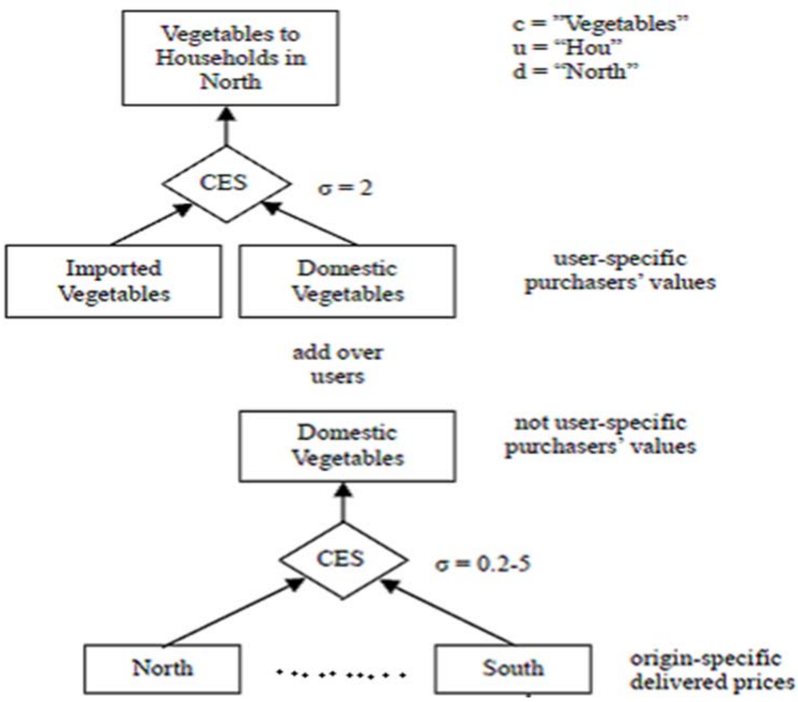


Figure 9. Inter-region trade decision



5. Key results of the MR-CGE assessment of the “extended” replacement cost

We brought in the replacement cost of the Kaomei wetland’s ecosystem service for water purification as estimated by Lin et al. (2011), which is 10,900 million Taiwan dollars (see Table 5b). In the MR-CGE simulation, we assumed a neoclassical short-run closure and brought in the investment expenditure of 10,900 million Taiwan dollars. Table 6 shows the key simulation result of induced regional output increase due to the investment expenditure on building a conventional wastewater treatment plant of same processing capacity as the Kaomei wetland.

Table 6 shows an 1.618 of nation-wide output multiplier for the estimated replacement cost offered by Kaomei for water purification function. This indicates a much larger replacement cost than the one Lin et al. (2011) estimated, which is 10,900 million Taiwan dollars. This is because the estimates of the “extended replacement cost” is embedded with the concepts of “opportunity cost” as well as the “spillover effect”, to which are referred by Bastiat’s (1850) “Broken Window Fallacy” and Leontief (1970). In other words, our results from the MR-CGE model may imply potential underestimation of the replacement cost measured in a straightforward way like Lin et al. (2011).

Should the Kaomei wetland being conserved, the spared expenditure for building the water purification facility of same processing capacity like Kaomei could be used instead for other good economic purposes, which would boost economic development of the regions and the nation, for example, more labor employment, more domestic production, and thus more income for households.

Table 6. Induced regional output increase: “extended” replacement cost of Kaomei wetland’s ecosystem service for water purification

Unit: mil.	1 North	2 Central	3 South	4 East	Total	
Change in reg. tot. prodution	2991	7007	1255	60	11313	
Change in reg. investment	375	7399	65	3	7841	
Change in reg. public investment	2	6992	0	0	6996	
Output multiplier of reg_public_investment	0.428	1.002	0.180	0.009	1.618	
Output multiplier_nat		1.618				
Change in reg. VA	1231	3282	456	26	4995	44%

6. Concluding remarks

Leontief (1970) demonstrated how environmental regulation increased GDP, in which cost of maintaining certain level of environmental quality turned out to be the top-up. Our MR-CGE results prompted us to further consider if GDP is a good measure of economic well-being. A misleading index for economic development may result in mis-allocation of limited resource of the economy as well as the free resource from the natural environment.

Kaomei was not paid a price (or value) commensurate with the brilliant job it has been quietly doing. Once the Kaomei wetland was converted into industrial/commercial built-up area, the government will have to build a surrogate water purification facility to render same level of environmental quality. This will cost the economy not just the face value of the construction bill, but could well be twice or even more. If the Kaomei could be conserved, the spared budget could be used to generate much greater economic payoff than the replacement cost of building a water purification facility with Kaomei’s processing capacity. Based on our study, it will be wise to not under-value ecosystem services, lest it may render mis-aligned strategy for sustainable development of the economy and the environment.

In addition, our study also suggested a need for recording in the economic accounting, such as Green GDP, the contribution of ecosystem services being provided by the environment free of charge. For the case of Taiwan, valuation of ecosystem service is planned, but not yet accounted for. Our approach offers an alternative measure for replacement cost in presenting the value of ecosystem services.

References

Bastiat, Frédéric. (1850). "That Which Is Seen, and That Which Is Not Seen," essay.

Barbier EB (2007). Valuing ecosystem services as productive inputs. Econ Policy 22:177–229.

Bateman, I., Mace, G., Fezzi, C., Atkinson, G., & Turner, K. (2011). Economic Analysis for Ecosystem Service Assessments. Environmental and Resource Economics, 48(2), 177-218. doi: 10.1007/s10640-010-9418-x

Bateman IJ, Day BH, Dupont D, Georgiou S (2009) Procedural invariance testing of the one-and-one-halfbound dichotomous choice elicitation method. Rev Econ Stat 91(4):806–820. doi:10.1162/rest.91.4.806

Boyer, Tracy, and Polasky Stephen. (2004). Valuing Urban Wetlands: A Review of Non-Market Valuation Studies. Wetlands. vol.4, issue 24. December 2004. 744–755.

Brown, M. T., and M. B. Vivas. (2005). Landscape development intensity index. Environmental Monitoring and Assessment 101:289-309.

Chen, T.-S., & Lin, H.-J. (2011). Application of a Landscape Development Intensity Index for Assessing Wetlands in Taiwan. Wetlands, 31(4), 745-756. doi: 10.1007/s13157-011-0191-6

Costanza et al. (1997). The value of the world's ecosystem services and natural capital. Nature 387:253-260.

Geber, U., & Björklund, J. (2002). The relationship between ecosystem services and purchased input in Swedish wastewater treatment systems — a case study. Ecological Engineering, 19(1), 97-117. doi: 10.1016/s0925-8574(02)00079-4

Heal GM, Barbier EB, Boyle KJ, Covich AP, Gloss SP, Hershner CH, Hoehn JP, Pringle CM, Polasky S, Segerson K, Shrader-Frechette K (2005) Valuing ecosystem services: toward better environmental decision making. The National Academies Press, Washington.

Horridge, J.M., Madden, J.R. and G. Wittwer (2005), "The impact of the 2002-03 drought on Australia", Journal of Policy Modeling, Vol 27/3, pp. 285-308.

Kaval P (2010). A summary of ecosystem service economic valuation methods and recommendations for future studies. Working paper series #10Department of Economics, University of Waikato.

Leontief, W. (1970). Environmental Repercussions and the Economic Structure: An Input-Output Approach. *The Review of Economics and Statistics, 52*(3), 262-271.

Leontief, Wassily W. (1986) Input-Output Economics. 2nd ed., New York: Oxford University Press.

Lin, H.-J. (2011). Valuation of Ecosystem Services of the Kaomei Wetland. Working paper.

Millennium Ecosystem Assessment (MA) (2005) Ecosystems and human well-being: a framework for assessment. Island Press, Washington DC.

TEEB (2010) The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB.

Wang (2007). National Land Use Survey Data. 國土利用調查成果應用發表會.