Inter-generational equity index for assessing environmental sustainability: An example on global warming

Tze-Chin Pan, Jehng-Jung Kao*

Institute of Environmental Engineering, National Chiao Tung University, Hsinchu 30039, Taiwan, ROC

A B S T R A C T

Inter-generational equity is essential for environmental sustainability. The current generation inherits an environment with a certain quality from the previous generation. The impact on the environment gradually exacerbates and accumulates over a period of time between two generations. However, currently there is no index available to assess inter-generational equity. Generally a typical environmental index is established to represent the environmental status in a specific year. This kind of index, although it presents the annual environmental variation, does not reflect the degree of change in environmental sustainability between two generations. Therefore, an inter-generational equity index (IGEI) and an endowment equation to examine the temporal trend of the changing environment are proposed for assessing inter-generational equity. To demonstrate the applicability of the endowment equation, an IGEI was established to assess the inter-generational equity of global warming. The global warming IGEI evaluates the status between two generations based on three sub-indexes; CO_2 emission, loss due to climate disasters, and the size of the existing forest area. The pressure–state–response (PSR) framework was adopted to explain the causal relationship between these three sub-indexes. According to the endowment rate determined by the proposed equation for each sub-index, the increase in CO_2 emission from 1980 to 2000 shows an obviously inequitable pattern between generations. Subsequently, the loss due to climate disasters between generations was also more serious. The size of the forest area, an important factor for reducing the impact of global warming, is unfortunately also decreasing significantly between generations. Using the endowment rate determined by the proposed endowment equation, the evaluation of the inter-generational equity is made possible and is demonstrated by the IGEI established for global warming.

© 2008 Elsevier Ltd. All rights reserved.

1. Introduction

The well-known document "Our Common Future" (WCED, 1987) established a widely accepted definition of sustainable development: "…development that meets the needs of the present without compromising the ability of future genera- tions to meet their own needs." Inter-generational equity has become an essential issue for sustainable development. The state of the environment of the current generation is inherited from the previous generation, and the current generation has the responsibility to maintain or improve this environmental quality and deliver it to the next generation (Young, 1995). The

environmental impact caused by activities in the current generation is accumulated over the time period of that generation and passed on to the next generation. (Syme et al., 2006). The current generation should do their best to stop the deterioration of the environment and instead improve it.

To assess the progress of improving the environmental sustainability, indicators are frequently used to measure that progress (Hezri and Hasan, 2004; Wilson et al., 2007). For instance, the Environmental Sustainability Index (Esty et al., 2005), Environmental Vulnerability Index (Kaly et al., 2004), and the Regional Quality of Life Counts (UK DEFRA, 2004) are three typical examples of these indicators. However, they are used to assess the environmental sustainability in a specific year and do not reflect the temporal inter-generational change of environmental sustainability. Although some indicators already have periodical records for many years, they merely show the variation of environmental quality, which does not explain the equity between generations. Therefore we propose an inter-generational equity index (IGEI) in this study.

To develop this proposed IGEI, an appropriate measure to reflect inter-generational changes is necessary. Unfortunately, no such measure is currently available. At present, the temporal environmental change is usually evaluated by comparing the difference between the two indicator values of the current and the previous years (OECD, 2001; EEA, 2002). However, this yearly difference measure may fluctuate substantially, especially when a special or unusual event happens during a specific year. Furthermore, inter-generational change must evaluate the status over a longer term. Therefore, an endowment equation is proposed in this study. The endowment rate determined by the proposed equation is used to measure the inheritance change, either positive or negative, between two generations.

Global warming is an important issue for environmental sustainability. Great attention must be paid to the inter-generational equity of global warming in order to make people aware of the importance of constantly improving the sustainability of the environment. Although several models are available (e.g. Shiell, 2003; Newell and Pizer, 2003; Grübler and Fujii, 1991) for analyzing inter-generational equity, they are complicated and not easy for the general public to understand. Therefore, the global warming IGEI (GW-IGEI) was developed to demonstrate the applicability of the proposed endowment rate and endowment equation. This study adopts the pressure, state, and response (PSR) framework (OECD, 2003) to explain the cause–effect relationships among the sub-indexes of the proposed GW-IGEI. The PSR framework can highlight the cause–effect relationships among sustainability issues. Three sub-indexes were selected, those of CO_2 emission, loss due to climate disasters, and the size of forest area, and they correspond to pressure, state, and response, respectively. The values of these three sub-indexes were determined using the proposed endowment equation for assessing the global warming inter-generational equity.

The remainder of this paper is organized as follows. In the next section the definition of "generation" is discussed. Then, the proposed endowment equation is described. Next, the three sub-indexes for global warming are explained. Finally, the establishment of the GW-IGEI is demonstrated and discussed.

2.   Generation

For assessing inter-generational equity, it is essential to first define a generation. There are two typical definitions. According to Edmunds and Turner (2002) and Miller (1999), a generation can be defined as a cohort born during a specific time period and having common historical experiences. The other one (e.g., Young, 1995; Oxford English Dictionary, 2008) defines a generation as a period of time between the birth of parents and their children. However, such definitions are used for specific historical or age-difference studies and are not appropriate for assessing environmental sustainability and inter-generational equity. Environmental problems impact on humans of all ages and should not focus on a few specific ages only. Since the industrial revolution, lifestyles have changed a great deal and the sustainability of the environment has also greatly been affected. At the same time, to reduce the impact for improving the environmental sustainability, a new life-style should be introduced (UNDP, 2007). Therefore, this study modified the definition of generation and defining it as people who live in the same era, and have a common lifestyle that impacts the environment or is influenced by the environment even though such a lifestyle-based generation has as yet not been studied nor defined.

For the time span of a generation, literatures in other areas (e.g., Verrelli et al., 2002; Oxford English Dictionary, 2008) usually define the time span of a generation between 20 and 30 years. However, the exponential advances of modern technology in recent decades has changed people's lifestyle rapidly (Rosa, 2003), and the resulting impact from human activities on the environment is increasing accordingly. Therefore, a generation span of 30 years is too long to present the environmental sustainability change. Furthermore, using the population growth as an example, as shown in Table 1, the world population increased from 0.3 billion to 1 billion over 1804 years, from 1 billion to 2 billion it took 123 years, and the intervals for increasing 1 billion population are getting shorter and shorter (UN, 1999). It might have been appropriate to set a generation longer than 20 years or more for assessing environmental sustainability about a 100 years ago, but it is no longer appropriate for such a long span to define a generation for assessing inter-generational equity in today's world, especially for many globally critical issues, such as global warming, water, food, etc. Although a generation span of 20 years is acceptable, currently available data for some environmental sustainability issues are not enough to produce meaningful results for further analyses. To produce a result for

Table 1 – World population.		
Year	Population	Interval to next billion
0	0.3 billion	1804 years
1804	1 billion	123 years
1927	2 billion	33 years
1960	3 billion	14 years
1974	4 billion	13 years
1987	5 billion	12 years
1999	6 billion	
Data source: United Nations (UN, 1999).		

such a long period of time, data from at least 40 years, 20 years for the current generation and the other 20 years for the previous generation, should be available. Since it is not, this study adopted 10 years as the span of a generation for assessing the environmental sustainability inter-generational equity.

3. Endowment equation

In the past, the temporal change of indicator values has often been evaluated by one of the following two equations.

$$R = \frac{Y_C}{Y_P} \tag{1}$$

$$R = \frac{Y_C - Y_P}{Y_P} \tag{2}$$

where R is the temporal change rate; and Y_C and Y_P are the values of an indicator for the current and previous years, respectively. Although both equations can reflect the relative temporal change between two specific years, they can not properly assess the inter-generational temporal change of sustainability. Both equations evaluate the values in two specific years only, and do not compare the values with a benchmark or target. Consequently it is difficult to assess how good the temporal change toward sustainability is, based on the change rates determined by the equations. For example, the change rate of the size of the global forest areas from 1970 to 1980 is 0.79% (FAO, 2007). According to the temporal change rate, this does not look like a serious problem. However, in fact, the area of forest lost is about 34 million hectares, and the sustainability between two generations has decreased substantially. The area of deforestation from 1961 to 1970 is about 42 million hectares, while the deforestation from 1961 to 1980 is about 76 million hectares. If the forest area in 1961 is set to be a desired target to recover to, then the deforestation in 1980 is 1.81 times more than that in 1970. Therefore, by including the target into the calculation, the extent of the environmental sustainability can be evaluated more clearly than by calculating the change rate by Eqs. (1) and (2).

To resolve the problem of applying Eqs. (1) and (2), this study proposes the following equation for assessing inter-generational equity.

$$R = \frac{T - G_C}{T - G_P} \tag{3}$$

where T is an exemplar that is expected to be achievable, although not actually achieved, during the period of both evaluated generations; G_C and G_P are the average values of an indicator for the current and previous generations, respectively. Since the value of an indicator in a specific year can not represent the overall environmental status of a generation and may fluctuate substantially during a generation, the average in the entire period of a generation is thus used instead.

Since by simply comparing indicator values themselves one can not know how far an indicator value is from an acceptable level, an appropriate target is needed. The proposed equation compares the distances between an exemplar and the indicator values in the current and previous generations. In order to enhance sustainability, the visions and goals are generally set with desired long-term ideal targets. However, an ideal target is frequently hard to achieve within one generation, especially when the environment inherited from previous generation is not good. In addition, the status of the environment changes dynamically between generations, and a fixed target is thus not appropriate for evaluating the inter-generational equity. Therefore, this study proposes an exemplar that is achievable in one generation as the benchmark. The exemplar is the best indicator value in current and previous generations. Once the exemplar has been achieved, even if it is only achieved once during both generations, it is a reasonable target.

In addition to setting an exemplar for establishing Eq. (3), this study also proposed an endowment equation to facilitate the assessment of assessing inter-generational equity. The endowment rate determined by the proposed equation can help the decision maker set a target rate for improving inter-generational equity. The endowment equation was developed based on the inheritance relationship between generations and the impact of current human activity on the next generation. The proposed equation is formulated as follows:

$$T - G_P = (T - G_C) \cdot (1 + e)^N \tag{4}$$

where e is the endowment rate for an indicator; and N is the number of years in a generation, i.e. 10 in the present study.

For pursuing inter-generational equity, the current generation has the obligation not to deteriorate the environment inherited from the last generation and pass it on in good shape to the next generation (Tobin, 1974). The proposed endowment equation compares the indicator values in the current and the previous generations to evaluate whether the current generation leaves a better environment to the next generation. For expressing the extent of inter-generational equity, the endowment rate indicates the temporal change which is either improving or worsening the inter-generational equity. According to the endowment rate, the decision maker can set a reasonable annual improvement rate to enhance the sustainability. Furthermore, while a desired target is pre-specified for the next generations, the endowment equation can be used to determine the minimally acceptable endowment rates that should be achieved in the next generations. Based on Eq. (4), the endowment rate for a specific target can be computed by the following equation:

$$e = \left[\frac{T - G_P}{T - G_C}\right]^{1/N} - 1 \tag{5}$$

When the endowment rate is smaller than zero, it indicates that the environment left to the next generation is not as good as that inherited from the previous generation and is a negative inter-generational equity. On the other hand, if the endowment rate is positive, it implies that the current generation improved or recovered the environment inherited from the previous generation, and is a positive inter-generational equity. The endowment rate can be used to express the extent of inter-generational equity.
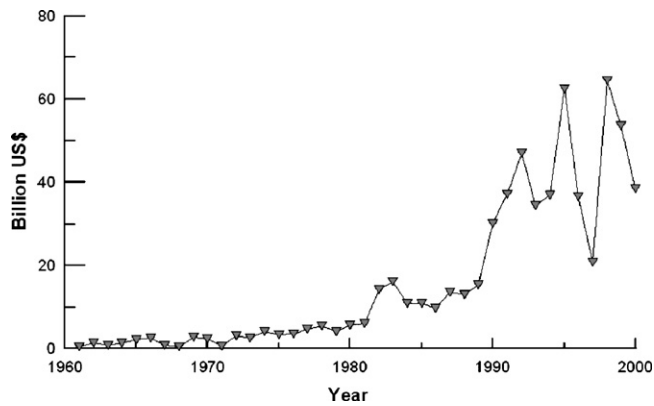
Fig. 1 – Annual value of loss due to climate disasters.

4. Global warming inter-generational equity index

In past few decades, the CO_2 emission from human activities has significantly increased, and the problem of global warming has become an important issue. Because CO_2 and other greenhouse gases can stay in the atmosphere for a long time, the CO_2 emitted in the previous generation often influences the current generation, and the CO_2 emitted in the current generation also influences future generations (MacLean, 1992). For assessing the inter-generational equity for global warming and to demonstrate the application of the proposed endowment equation, this study developed a global warming inter-generational equity index (GW-IGEI).

Since there are multiple sub-indexes related to the issue of global warming, the PSR (OECD, 2003) framework is applied to explain the cause–effect relationships among the sub-indexes. The amount of CO_2 (or e CO_2) emission is the major factor in global warming (IPCC, 2007b; Donnelly et al., 2004). It is therefore regarded as the pressure sub-index that represents the impact from human activities on the environment. The CO_2 emission in the current generation will impact on the next generation and is thus an essential sub-index for reflecting the inter-generational equity for global warming.

The state sub-index of the PSR framework should relate directly to the generation impact for assessing the inter-generational equity. Increasing CO_2 emissions can speed up global warming and is likely to worsen climate disasters (IPCC, 2007a,b). For evaluating the impact of climate disasters, the losses from climate disasters are adopted. The loss due to climate disasters, as illustrated in Fig. 1, has obviously been getting worse in recent generations, and is a significant problem for inter-generational equity. Therefore, this study selected the loss due to climate disasters to be the state sub-index.

Forests play an important role in mitigating global warming by absorbing and stocking CO_2 (Marland et al., 2003; Kauppi, 2003). Furthermore, according to IPCC (2007b), deforestation is the second largest greenhouse gases emission source, and afforestation and reforestation are effective strategies to reduce CO_2 emissions (Kindermann et al., 2008; Myneni et al., 2001). Therefore, the size of the forest area can be regarded as the response sub-index. There are other sub-indexes such as renewable electric power generation, world

total energy consumption, or fossil fuel consumption that are also related to the development of the GW-IGEI. However, not enough data is currently available for some of them. In addition, too many sub-indexes would make the assessment of the inter-generational equity too complicated in this initial study stage and subsequently make it difficult to demonstrate the applicability of the proposed endowment equation. Therefore the GW-IGEI developed in this paper is evaluated based on the three sub-indexes only.

The annual values of CO_2 emission, losses from climate disasters, and the size of the forest areas were collected from the World Development Indicators database (World Bank, 2007), Emergency Disasters Database (CRED, 2007), and FAOSTAT (FAO, 2007), respectively. The proposed endowment equation was applied to compute the endowment rates of the three sub-indexes, and the endowment rates of the three sub-indexes was used to assess the change of inter-generational equity.

5. Discussion

For assessing the inter-generational equity of global warming the proposed endowment rates of the three sub-indexes, CO_2 emission, loss due to climate disasters, and the size of the forest area, were determined. They are illustrated in Figs. 2–4, respectively. These figures show the average values of the three sub-indexes in the current and the previous generations, with the bar charts indicating the endowment rates.

5.1. CO_2 emission

Fig. 2 shows that because the CO_2 emissions increase continuously in all generations relative to the previous generation, the endowment rates are all negative. This negative endowment rate indicates that all generations passed on more CO_2 to their next generations than they inherited from their previous generations, and therefore this implies a negative inter-generational equity.

Since the inter-generational equity should consider the inheritance relationship between current and previous gen-
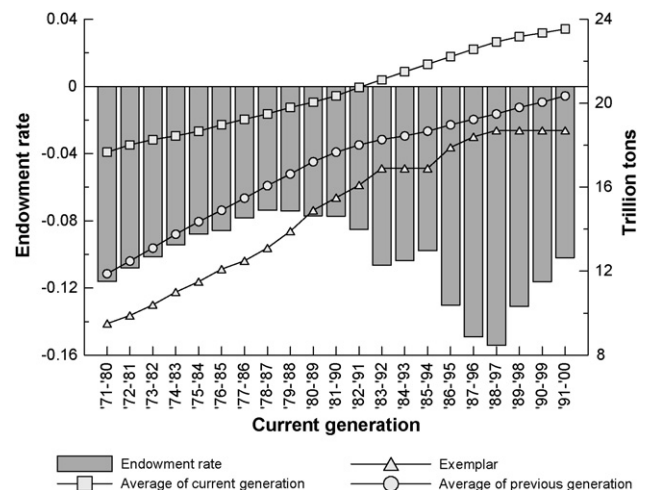

Fig. 2 – The generation endowment rate, average, and exemplar for CO_2 emission.
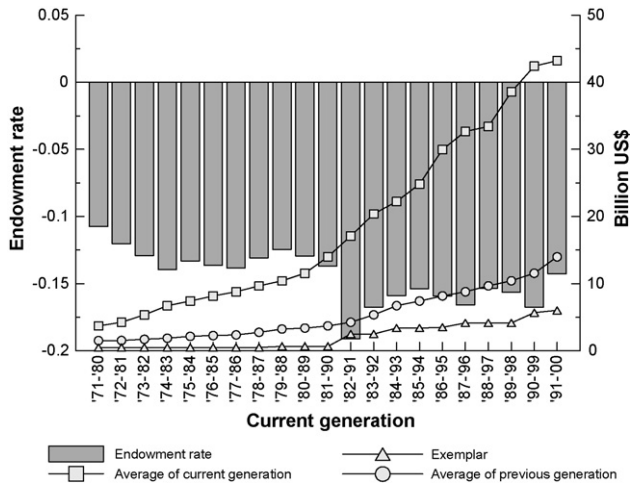
Fig. 3 – The generation endowment rate, average, and
exemplar for loss due to climate disasters.

erations, the changing trend of CO_2 emission endowment
rates may not be consistent with the increasing trend of CO_2
emissions. For example, the trend of generation averages for
current and previous generations keeps increasing, but the
endowment rates for the generations from 1971–1980 to 1978–
1987 are improved. In these generations, the increase of CO_2
emission for the current generation was less than the increase
observed in the previous generation. Therefore, several such
endowment rates were improved.

The worst endowment rate was −16%, for the generation
during 1989–1997. For inter-generational equity, a generation
should at least reduce its CO_2 emission to the level emitted by
the previous generation. Therefore, the generation of 1998–
2007 is expected to reduce its annual CO_2 emissions by about
16% for achieving this goal.

5.2. Loss due to climate disasters

In this study, the loss due to climate disasters includes the loss
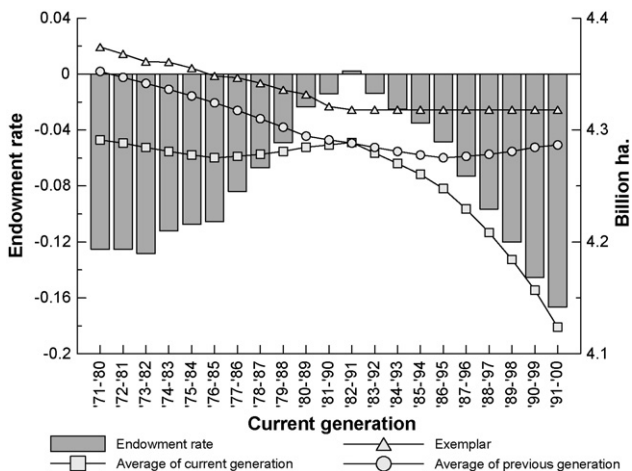from floods, wind storms, extreme temperatures, and

Fig. 4 – The generation endowment rate, average, and
exemplar for the size of forest area.

drought. The endowment rates for loss due to climate
disasters are shown in Fig. 3. The average for the current
generations is worse than that from previous generations and
clearly indicates an unequal pattern among generations. The
endowment rates in all generations are thus all negative also.

Since the loss averages rose significantly during the 1982–
1991 generation, the endowment rates afterwards were all
worse than those before. The worst endowment rate, −19.1%,
was for the generation of 1982–1991. As shown in Fig. 1, since
the annual values before 1982 do not vary much and are not
significantly high, the exemplar is close to the generation
average, and thus the difference between the average and the
exemplar is not large. However, the loss became serious after
the 1982–1991 generation and subsequently made the endow-
ment rate worse. This also shows that the 1982–1991
generation is the critical generation that significantly deterio-
rated the inter-generation equity.

5.3. Forest area

The endowment rates and the generation averages of the
forests are shown in Fig. 4. The annual size of the forests for
the purpose of calculating the generation average was
collected from FAOSTAT (FAO, 2007) and Global Forest
Resources Assessment (FAO, 2006). However, the annual sizes
of the forests from 1995 to 1999 are not available and therefore
values were interpolated from available data of other years.

As shown in Fig. 4, the average sizes of the forest areas in
both current and previous generations for the generations
from 1971–1980 to 1982–1991 are getting close, and the
endowment rates in these generations had thus also gradually
improved. Since the average for the 1982–1991 generation was
larger than for its previous generation, the associated
endowment rate is positive, showing an improvement in
inter-generational equity. It indicates that the 1982–1992
generation increased the forest inherited from its previous
generation and that it left more forest areas to the next
generation. Unfortunately, this positive inter-generational
equity was observed for 1 year only, and the endowment
rates have become increasingly worse since 1992. As per the
principle by Vojnovic (1995), to assure inter-generational
equity for renewable resources, the consumption rate should
not exceed the regeneration rate. However, as illustrated in
Fig. 4, the sizes of the forests have steadily deteriorated in
recent generations, with the amount of deterioration being
quite significant. It is imperative that an effective strategy is
implemented to stop this deforestation trend.

6. Conclusion

This study proposed a method for establishing an index for
assessing inter-generational equity. Since a typical environ-
mental index can not properly represent the inter-genera-
tional equity, this study developed an endowment equation
and an endowment rate determined by the proposed equation
based on an achievable exemplar to evaluate the inheritance
change between previous and current generations.

Global warming is probably one of the most critical issues to
assess for inter-generational equity. The proposed method

demonstrated the establishment of a global warming inter-generational index. This study applied the PSR framework (OECD, 2003) to explain the cause–effect relationships among the three sub-indexes of CO_2 emissions, losses from climate disasters, and the size of the forest areas, corresponding to Pressure, State, and Response, respectively. The endowment rates of the three sub-indexes were determined by the endowment equation to illustrate the status of inter-genera-tional equity for global warming. Because the pressure sub-index of CO_2 emissions keeps increasing, all the endowment rates for the CO_2 emissions from the 1971–1980 to 1991–2000 generations indicate negative inter-generation equity. Due to the pressure of the steadily increasing CO_2 emissions, the endowment rates of the state sub-index of the losses from climate disasters after the 1982–1991 generation are signifi-cantly worse than those before the 1982–1991 generation. The endowment rate of the size of the forest area is only positive in the generation during 1982–1991 and keeps decreasing in other periods. If the forest size is significantly recovered it is expected to be able to stop the pressure and the state sub-indexes from getting worse. According to the endowment rates determined by the proposed endowment equation, the inter-generation equity for global warming is obviously negative and must be remedied as soon as possible. Apart from the global warming issue, our proposed method is also expected to be applicable for establishing other inter-generation equity indexes, although further studies are necessary to demonstrate this applicability.

Acknowledgment

R E F E R E N C E S

Centre for Research on the Epidemiology of Disasters (CRED), 2007. Emergency Events Database. http://www.emdat.be/.
Donnelly, A., Jones, M.B., Sweeney, J., 2004. A review of indicators of climate change for use in Ireland. Int. J. Biometeorol. 49, 1–12.
Edmunds, J., Turner, B.S., 2002. Generations, Culture and Society. Open University Press, Buckingham, p. 141.
Esty, D.C., Levy, M., Srebotnjak, T., de Sherbinin, A., 2005. 2005 Environmental Sustainability Index: Benchmarking National Environmental Stewardship. Yale Center for Environmental Law and Policy & Center for International Earth Science Information Network, Davos, p. 408.
European Environment Agency (EEA), 2002. Environmental Signals 2002. Environmental Assessment Report No. 9. Office for Official Publications of the European Communities, Luxembourg, 149 pp.
Food Agriculture Organization of the United Nations (FAO), 2006. Global Forest Resources Assessment 2005. FAO, Rome, 350 pp.
Food and Agriculture Organization of the United Nations (FAO), 2007. FAOSTAT. http://faostat.fao.org/site/418/DesktopDefault.aspx?PageID=418.
Grübler, A., Fujii, Y., 1991. Inter-generational and spatial equity issues of carbon accounts. Energy 16 (11/12), 1397–1416.

Hezri, A.A., Hasan, M.N., 2004. Management framework for sustainable development indicators in the State of Selangor, Malaysia. Ecol. Indicat. 4, 287–304.
Intergovernmental Panel on Climate Change (IPCC), 2007a. Summary for policymakers. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E. (Eds.), Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, pp. 7–22.
Intergovernmental Panel on Climate Change (IPCC), 2007b. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, 104 pp.
Kaly, U.L., Pratt, C.R., Mitchell, J., 2004. The Demonstration Environmental Vulnerability Index (EVI) 2004. SOPAC Technical Report 384, 323 pp.
Kauppi, P.E., 2003. New, low estimate for carbon stock in global forest vegetation based on inventory data. Silva Fennica 37 (4), 451–457.
Kindermann, G., Obersteiner, M., Sohngen, B., Sathaye, J., Andrasko, K., Rametsteiner, E., Schlamadinger, B., Wunder, S., Beach, R., 2008. Global cost estimates of reducing carbon emissions through avoided deforestation. Proc. Natl. Acad. Sci. U.S.A. 105 (30), 10302–10307.
MacLean, D., 1992. Intergenerational equity. In: White, J.C. (Ed.), Global Climate Change: Linking Energy, Environment, Economy, and Equity. Plenum Press, New York, pp. 177–181.
Marland, G., Pielke Sr., R.A., Apps, M., Avissar, R., Betts, R.A., Davis, K.J., Frumhoff, P.C., Jackson, S.T., Joyce, L.A., Kauppi, P., Katzenberg, J., MacDickie, K.G., Neison, R.P., O'Niles, J., Niyogy, D., Norby, R.J., Pena, N., Sampson, N., Xue, Y., 2003. The climatic impacts of land surface change and carbon management, and the implications for climate-change mitigation policy. Climate Policy 3, 149–157.
Miller, R.L., 1999. Researching Life Stories and Family Histories. Sage Publication, London, p. 192.
Myneni, R., Dong, J., Tucker, C.J., Kaufmann, R.K., Kauppi, P.E., Liski, J., Zhou, L., Alexeyev, V., Hughes, M.K., 2001. A large carbon sink in the woody biomass of Northern forests. Proc. Natl. Acad. Sci. U.S.A. 98 (26), 14784–14789.
Newell, R.G., Pizer, W.A., 2003. Discounting the distant future: how much do uncertain rates increase valuations? J. Environ. Econ. Manage. 46, 52–71.
Organisation for Economic Co-operation Development (OECD), 2001. OECD Environmental Indicators: Towards Sustainable Development. OECD, Paris, 155 pp.
Organisation for Economic Co-operation Development (OECD), 2003. OECD Environmental Indicators: Development, Measurement and Use. OECD, Paris, 37 pp.
Oxford English Dictionary, 2008, Oxford English Dictionary Online. Retrieved July 15, 2008, from http://dictionary.oed.com.
Rosa, H., 2003. Social acceleration: ethical and political consequences of a desynchronized high-speed society. Constellations 10, 3–33.
Shiell, L., 2003. Descriptive, prescriptive and second-best approaches to the control of global greenhouse gas emissions. J. Public Econ. 87, 1431–1452.
Syme, G.J., Kals, E., Nancarrow, B.E., Montada, L., 2006. Ecological risks and community perceptions of fairness and justice: a cross-cultural model. Hum. Ecol. Risk Assess. 12, 102–119.
Tobin, J., 1974. What is permanent endowment income? Am. Econ. Rev. 64 (2), 427–432.

United Kingdom Department for Environment Food Rural Affairs (UK DEFRA), 2004. Regional Quality of Life Counts. UK DEFRA, London, 91 pp.

United Nations (UN), 1999. The World at Six Billion. United nations Population Division. Department of Economic and Social Affairs, United Nations Secretariat, New York, 63 pp.

United Nations Development Programme (UNDP), 2007. Human Development Report 2007/2008 Fighting Climate Change: Human Solidarity in a Divided World. Palgrave Macmillan, New York, 399 pp.

Verrelli, B.C., McDonald, J.H., Argyropoulos, G., Destro-Bisol, G., Froment, A., Drousiotou, A., Lefranc, G., Helal, A.N., Loiselet, J., Tishkoff, S.A., 2002. Evidence for balancing selection from nucleotide sequence analyses of human G6PD. Am. J. Hum. Genet. 71, 1112–1128.

Vojnovic, I., 1995. Intergenerational and intragenerational equity requirements for sustainability. Environ. Conserv. 22 (3), 223–228.

Wilson, J., Tyedmers, P., Pelot, R., 2007. Contrasting and comparing sustainable development indicator metrics. Ecol. Indicat. 7, 299–314.

World Bank, 2007. World Development Indicators Database. http://www.worldbank.org/data/onlinedatabases/onlinedatabases.html.

World Commission on Environment Development (WCED), 1987. Our Common Future. Oxford University Press, Oxford, 383 pp.

Young, M.D., 1995. Inter-generational equity, the precautionary principle and ecologically sustainable development. Nat. Resour. 31 (1), 16–27.