IMPLICATIONS OF ECOLOGICAL FOOTPRINT VALUES FOR SELECTED EU MEMBERS

Mircea Saveanu*

Abstract: *We analyse the state of the environment for 24 EU member states, using the concept of ecological footprint. Findings suggest that 20 of the 24 analysed states are pushing their environment past its yearly regenerative limits. Of these, 10 have surpassed this value by at least two-fold. A few outliers have gone well beyond even this mark. Four member states have yet to reach the regenerative limit of their lands, and could thusly be viewed as faring better, in terms of the health of their environment. The mechanism that allows overtly ecologicaly unsustainable countries to thrive is discussed.*

Keyword: ecological footprint; sustainability; biocapacity; carrying capacity; international trade
JEL Classification: Q01; Q56; Q57

INTRODUCTION

Assessing the state of an economy is a huge undertaking, and the complexity it entails is on the scale of the nations measured. Problems can arise from the onset, as the method used for analysing an economy can lead to very different results. One can analyse an economy with regards to its output (GDP), which is the most popular method used today. Other methods include checking for the inequalities in an economy, and then the Gini index would be used. A more holistic approach, although far from perfect, would be to analyse the Human Development Index for a given country, which takes into account the education, income and health of the citizens. These could all be broadly described as economic indexes.

The world in which we live is far more complex though, and a simple analysis of the output of an economy or the spending patterns of its citizens simply will not do justice. Given the fact that one of the key problems humankind is facing at this moment is related to the environment, concerns have been voiced with regard to the inability of many of aforementioned indexes to accurately account for the loss in biodiversity, the negative effects of human-induced global warming and pollutants, the changes in the natural hydrological cycle, etc. (e.g. Daly, 1992, 2005).

Following years of research, we now have some measures of these effects and, accordingly, some aggregate indexes for the state of the environment in a given economy. These

* Ph.D. student at Alexandru Ioan Cuza University of Iasi, Romania; e-mail: mircea.saveanu@feaa.uaic.ro; mircea_saveanu@yahoo.com.

include: the Index of Sustainable Economic Welfare (Daily & Cobb, 1989; Cobb *et al*., 1995) and the Genuine Progress Indicator (UNDP, 1996). These are holistic indexes, on par with the HDI, and are regarded as the next generation measurement tools for an economy, because they reveal much more than the economic output of a country.

With regards to the environment, Rees and Wackernagel (1994) developed a measurement for the environmental state of an economy called the environmental footprint[*]. The strength of this index lies in the fact that it focuses on a single aspect, the environment, eliminating the haphazard job of aggregating qualitatively different entities, while the results it returns are meaningful and can be correlated with the information given by economical indexes, say GDP.

1. METHODOLOGY & PRELIMINARY DATA

The ecological footprint index consists of two parts: the effective ecological footprint of a community on the land it occupies, and the biocapacity of the land. The effective ecological footprint of a community is the mark left on the land by the inhabitants (both sink and source side[†]), as measured in global hectares[‡]. The biocapacity is the annual capacity of the land to regenerate (both sink and source side), as measured also in global hectares. Therefore, if one substracts the effective ecological footprint from the biocapacity, one can get a crude measurement of the strain on the environment put by the inhabitants. There is room for improvement (for example, the ecological footprint methodology does not account for the life-support and human health and welfare functions of the environment – see Ekins, 2003), but the method has already been implemented by some Governments, in order to assess their impact on the environment. For the EU, the following data could be accessed:

Table 1 – Ecological footprint data for 24 EU member states

Country*	Ecological footprint of consumption	Biocapacity	Gross ecological footprint
Austria	4.89	2.99	-1.9
Belgium	5.7	1.09	-4.61
Bulgaria	3.25	2.66	-0.59

[*]Ecological Economics released a special issue concerning commentaries on the concept of ecological economics (vol. 32, issue 3, March 2000); interesting discutions in Ayres (2000), Costanza (2000a) and Rees (2000).
[†]Source side = the ecosystem functions which provide humans with natural resources; sink side = the ecosystem functions which absorb the human wastes and serve to reintegrate the resulting chemicals in the natural bio-chemical cycles. See Armsworth *et al*. (2004).
[‡]Equals a hectare of average productivity.

Croatia	3.34	1.8	-1.54
Czech Rep.	5.32	2.64	-2.68
Denmark	7.19	5.19	-2
Estonia	6.42	8.99	2.57
Finland	5.51	12.99	7.48
France	4.6	2.83	-1.77
Germany	4.03	1.86	-2.17
Greece	5.76	1.36	-4.4
Hungary	3.23	2.58	-0.65
Ireland	8.19	4.26	-3.93
Italy	4.94	1.03	-3.91
Latvia	4.6	7.24	2.64
Lithuania	3.32	3.66	0.34
Netherlands	4.6	1.05	-3.55
Poland	3.89	1.84	-2.05
Portugal	4.37	1.18	-3.19
Romania	2.67	2.27	-0.4
Slovakia	4.94	2.68	-2.26
Slovenia	3.89	2.36	-1.53
Spain	5.63	1.32	-4.31
United Kingdom	6.12	1.58	-4.54
* Data unavailable for Cyprus, Luxembourg, Malta and Sweden			

Source: GFN 2010 (data for 2007)

However, we can, from the given data, deduce more than that. If we define δ as:

$$\delta = \frac{ecological\ footprint\ of\ consumption}{biocapacity} \cdot 100,$$

then we can get a sense of the intensity of the process taking place. Computing for the data in the previous table, we arrive at the following results:

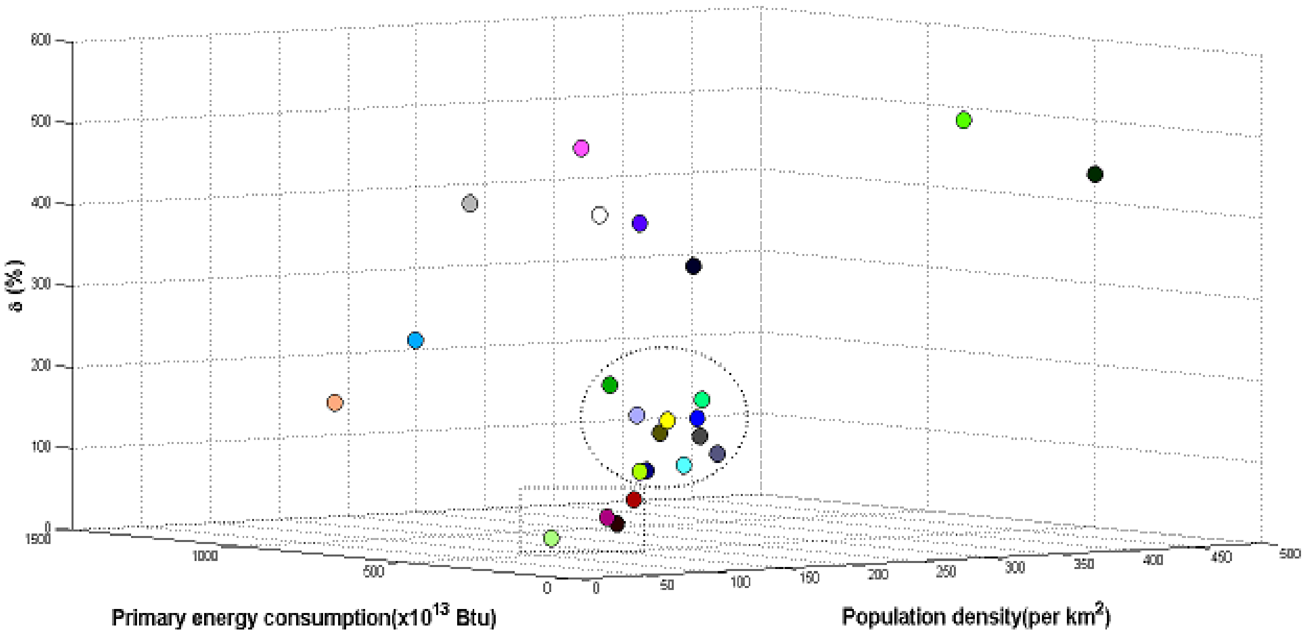
Table 2 – δ figures, based on the data from previous table

Countries with a positive gross ecological footprint 16.66%		Countries with a negative gross ecological footprint 83.33%	
Of which: Estonia Finland Latvia Lithuania	δ= 71.41% 42.41% 63.53% 90.71%	Of which: Austria Belgium Bulgaria Croatia Czech Rep. Denmark	δ= 163.5% 522.9% 122.1% 185.5% 201.5% 138.5%

		France	162.5%
		Germany	216.6%
		Greece	423.5%
		Hungary	125.1%
		Ireland	192.2%
		Italy	479.6%
		Netherlands	438.0%
		Poland	211.4%
		Portugal	370.3%
		Romania	117.6%
		Slovakia	184.3%
		Slovenia	164.8%
		Spain	426.5%
		United Kingdom	387.3%

Source: own calculations, based on the previous table

Figure 1 – 3D scatter plot of the selected EU countries. The top performing EU member states, GDP wise, are also characterised by a high δ value



For data sources, see Table 3

Table 3 – Detailed data for the scatter plot (format: country code* (x; y; z values respectively))

FI (17.4; 135.1; 42.4)	HU (108.1; 112.4; 125.1)	IE (63.7; 70.3; 192.2)	EL (85.6; 150.9; 423.5)
LV (36.5; 17.3; 63.5)	DK (126.7; 88.5; 138.5)	CZ (133.8; 164.6; 201.5)	UK (250.8; 956.1; 387.3)
EE (30.9; 23.1; 71.4)	SI (100.2; 31.9; 164.8)	PL (121.9; 391.8; 211.4)	SP (89.4; 676.1; 426.5)
LT (53.9; 38.6; 90.7)	AT (100.7; 154.4; 163.5)	FR (100.9; 1129.5; 162.5)	IT (201.2; 803.9; 479.6)
BG (69; 84.1; 122.1)	HR (78.4; 39.5; 185.5)	DE (230.4; 1422.6; 216.6)	NL (485.3; 435.5; 438)
RO (93.7; 166.2; 117.6)	SK (110.1; 79.2; 184.3)	PT (115.2; 112.8; 370.3)	BE (350.4; 273.6; 522.9)
The order of the countries is given by their marker position in the scatter plot, from bottom to top of the graph * For a list of country codes and their corresponding country, see Table 4, at the end of the document			

Source: for population densities (x values), Eurostat (2013); for primary energy consumption (y values), EIA (2013); δ values (z values), based on own calculations. All values are computed using data for 2007

2. RESULTS AND DISCUSSION

At a first glance, the results are somewhat grim: only 4 out of the 24 EU members for which we could obtain data have a positive gross ecological footprint. We interpret this as meaning that 4 countries out of the 24 studied states place a strain on their environment (source and sink side wise) less than the regenerative capacities of the land occupied. Conversely, 20 countries were, for the year 2007, overshooting the pressure on their environment, by taking in more resources than the land can regenerate, dumping more wastes than it can assimilate, or both.

The ecological footprint concept depends on two components: the effective ecological footprint of the given community and the biocapacity of the land to regenerate. Both of these quantities, as measured in global hectares, can fluctuate yearly, which means that the figures in the previous tables can vary from year to year. Given this fact, we can exclude one country that is near unity (δ=1), because Lithuania, which scored a δ of 90.71% for 2007, can go above 100% the next year, due to either a drop in biocapacity (from natural or artificial causes), an increase in the effective ecological footprint (due to increased human activity, for example), or a concurrence of both these effects. By eliminating Lithuania, as an inconclusive case, we are left with 23 countries.

Although we have only eliminated one country, the strongest message is conveyed by the countries with δ values situated furthest from 1. These outliers tell us the most about the impact of the economic growth on the environment. Before going into an analysis of those countries, we should first clarify what δ=1 means. There is a growing body of literature (although not from mainstream economics, and much of it coming from other fields, such as biology), which suggests that ecosystems provide valuable (although weakly quantifiable) assets for humankind (inter alia, Costanza & Daly, 1992; Vitousek, 1994; Chapin III *et al*., 1997; Costanza *et al*., 1997; Myers, 1997; Daily *et al*., 2000; Balnavera *et al*., 2001; Heal, 2004;). These include such functions as: complex and diverse genetic repository (through biodiversity), maintenance of the hydrological cycle, maintenance of the carbon cycle, maintenance of the nitrogen cycle, control over the climate, etc.

Focusing on just the biodiversity aspect, which has provided incommensurable assets in the past, and will undoubtedly provide more in the future, it is clear that any patch of land that has a δ value of 1 leaves little room for biodiversity to flourish. Much revenue is earned via tourism, due to biodiversity; many pharmaceuticals are derived from compounds found in wild flora or fauna. There is also a generally accepted theory in biology, which suggests that ecosystem resilience is highly dependent on the diversity of its flora and fauna (Tilman & Downing, 1994; Tilman *et al*., 1996; Tilman *et al*., 1997; Tilman *et al*., 2006). This places even more value on biodiversity, due to the strengthening role it plays in the environment[*].

These are all legitimate reasons not to discard the natural environment as a whole, when assessing the health of an economy. The implications of our reasoning are that a δ value equal to 1, while feasible strictly from the perspective of the human community, exhausts the source functions, the sink functions, or both, of the given environment, therefore leaving little for the local flora or fauna to thrive on. The inherent losses in biodiversity in such cases lead to a lowered resilience for the ecosystem, which in turn boomerangs back to more losses in biodiversity. Finally, due to the fact that biodiversity is tied in complex ways to the ecosystem, this leads to a drop in the biocapacity of the land, therefore reducing the sink functions, the source functions, or both (this effect can readily be seen in the impoverishment of the lands, due to the modern usage of large scale monocultures).

The previous paragraphs add weight to an already alarming situation. Going back to the analysis, we conclude that 10 of the 24 countries for which data was available, have overshot the regenerative capacities of their appropriated land by a factor of at least 2; 7 of these

[*]Determining, however, even a *grosso modo* value for the benefits accrued from ecosystems is a very difficult undertaking (*e.g*. Costanza & Folke, 1997; Costanza 2000b; Heal 2000). For an attempt at measuring these benefits see Costanza *et al*. (1997). For the uncertainty regarding such evaluations, see Arrow & Fisher (1974).

countries have surpassed the regenerative limit by a factor of 3; Spain, Greece, Italy, Netherlands and Belgium have exceeded this limit by more than 4 times. In simple terms, in order for these last 5 countries to be ecologically sustainable, at least with regards to the human appropriation of the sink and source functions of the ecosystem, the lands they possess would have to be 4 times larger in surface size[*]. Of the 3 remaining countries (those with a positive ecological footprint - Lithuania was excluded from the analysis), only Finland is using less than half the regenerative capacity of the land it possesses.

One might ask then, if so many countries are actually exceeding the carrying capacity of the land they appropriate, how can their communities still thrive? Many of the countries with a negative ecological footprint consist of highly developed economies, and would otherwise be seen as models for societal and economic development. How can some of these countries fail so hard at being ecologically friendly? The answer to this question is unclear, and the question in itself could be the subject of an entire thesis. It is beyond the scope of this article to come up with arguments supporting one side or the other. It is highly probable that the ecological footprint correlates positively with the energy consumption in a economy (although one might be right in pointing out that the energy intensity of a country is just as much a telling index as the primary energy consumption, since it reveals much about the efficiency in using the said energy), and also with the population density of that country[†].

Clearly, there are other factors at work here, besides the ones mentioned, and some of them might not even be of a physical and quantifiable nature. Psychological factors[‡], culturally induced behaviors, the impact of religion, traditions, etc., all might have a role in explaining the ecological footprint of a given country, and many of these factors could be unique to the given country, which would imply that making generalizations on the subject is a hazardous enterprise. But if determining the causes clearly requires more research, in many fields of the human knowledge, not just economics, the mechanism that sustains this process is clear: many countries can afford to go beyond the regenerative limits of the lands they own, simply because they are *importing* biocapacity. Many developed countries can afford to undergo long periods characterised by a negative ecological footprint, because there are other countries which are in

[*] As usual, the same assumption of an average productivity hectare is assumed.
[†] Notice that in Figure 1, all the countries with either high population density or high energy consumption have similarly high δ values. In the same figure, the dotted rectangle denotes the four countries with a positive gross ecological footprint value, while the dotted elipse encompases countries with similar x/y/z values. The remaining outliers are countries with a high δ value (>200).
[‡] For some interesting research in the field of environmental psychology, see *inter alia*, Proshansky *et al*. (1983); Hidalgo & Hernandez (2001); Schultz (2002); Giuliani (2003); Mayer and Frantz (2004); Schultz *et al*. (2004).

effect creating carrying capacity and, at a global level, this helps lessen the environmental impact. These countries rarely accrue benefits for this, although there are mechanisms which, in time, will probably alleviate the problem (one such mechanism might be the Clean Development Mechanism; for some promising results in this respect, see Castro *et al*., 2000).

Some examples include: developed countries that have destroyed much of their natural biodiversity can still benefit from the genetic richness of flora and fauna found in less developed countries, and in fact this is happening all the time, as researchers (generally located in the highly developed countries) travel to less developed countries and, after years of research, return with their fruits of labor and introduce pharmaceuticals and other products in the global market. This would not be possible if less developed countries would have appropriated much of the ecosystem functions, but nor would it be possible if the research teams from the highly developed countries would be inexistent. Another example involves the carbon cycle. Forests play a crucial role in this cycle, because, through photosynthesis, carbon is fixated, and, in the process, oxygen is released (which is vital for humankind). The fact that some countries have a negative ecological footprint could be indicative of a deficiency in the carbon cycle (caused by deforestation). The carbon cycle is not however a local phenomenon, which means that developed countries can afford this loss, as long as other countries, knowingly or not, keep their forests pristine. This reasoning can be applied to most of the contributions that an ecosystem has to human society. In a sense, the developed countries that show a negative ecological footprint are owing their existence to borrowed carrying capacity, *imported* from the less developed countries, and most of the time the latter receive only moderate compensation for their services.

CONCLUSIONS

This article focused on the ecological problems that some EU members have, and the indicator used was their ecological footprint. We analysed 24 of the 28 members, because information on Cyprus, Malta, Luxembourg and Sweden could not be obtained. Given the particular geography and population density of Cyprus, we could hypothesise a negative ecological footprint, while Sweden would most likely have a positive ecological footprint, since it is one of the least populated countries in the world, and has sprawling forests. Malta most likely is on par with Cyprus, while for Luxembourg, we can only guess that it might follow the trend set by the majority of EU members. This are all speculations, though. For the countries we have had data, the following conclusions can be emphasised:

- 20 of the 24 analysed countries have overshot the regenerative capacities of their land, for the year 2007. This means that, for that year, either the source functions of the ecosystem have been surpassed, the sink functions have been exceeded, or both;
- 4 countries (Estonia, Finland, Latvia and Lithuania) returned a positive ecological footprint, although one (Lithuania) remains inconclusive, due to the contiguity of the values of ecological footprint of consumption (3.32) and biocapacity (3.66);
- of the countries with a negative ecological footprint, 10 of the 24 have overshot the regenerative capacities of the appropriated land by a factor of at least 2; 7 of these countries have surpassed the regenerative limit by a factor of 3; Spain, Greece, Italy, Netherlands and Belgium have exceeded this limit by more than 4 times;
- Finland is the country with the lowest gross ecological footprint value, since, for 2007, it had used the source and sink functions of the ecosystem up to less than a half of its regenerative capacity;
- all the countries with a negative gross ecological footprint value are ecologically unsustainable, and their continued existence is due to the preservation of ecosystems in mostly lesser developed countries. This situation is poorly addressed by the global market, as some ecosystem functions (like the role in the global hydrological/nitrogen/carbon cycle) have yet to bring about consistent financial benefits for these countries.

ANNEX

Table 4 – Country codes used and their corresponding country

Austria	AT	Estonia	EE	Ireland	IE	Portugal	PT
Belgium	BE	Finland	FI	Italy	IT	Romania	RO
Bulgaria	BG	France	FR	Latvia	LV	Slovakia	SK
Croatia	HR	Germany	DE	Lithuania	LT	Slovenia	SI
Czech Rep.	CZ	Greece	EL	Netherlands	NL	Spain	SP
Denmark	DK	Hungary	HU	Poland	PL	United Kingdom	UK

REFERENCES

Arrow, K., Fisher, A. (1974) *Environmental preservation, uncertainty, and irreversibility*, The quarterly journal of economics, vol. 88, no. 2, pp. 312-319. DOI: http://dx.doi.org/10.2307/1883074

Armsworth, P., Kendall, B., Davis, F. (2004) *An introduction to biodiversity concepts for environmental economists*, Resource and energy economics, vol. 26, no. 2, pp. 115-136. DOI: http://dx.doi.org/10.1016/j.reseneeco.2003.11.003

Ayres, R. (2000) *Commentary on the utility of the ecological footprint concept*. Ecological Economics, vol. 32, no.3, pp. 347-349.

Balnavera, P., Daily, G., Ehrlich, P., Ricketts, T., Bailey, S.A., Kark, S., Kremen, C., Pereira, H. (2001) *Conserving biodiversity and ecosystem services*, Science, vol. 291, no. 5511, p. 2047. DOI: http://dx.doi.org/10.1126/science.291.5511.2047

Castro, R., Tattenbach, F., Gamez, L. & Olson, N. (2000) *The Costa Rican experience with market instruments to mitigate climate change and conserve biodiversity*, Environmental monitoring and assessment, vol. 61, no. 1, pp. 75-92. DOI: http://dx.doi.org/10.1023/A:1006366118268

Chapin III, S., Walker, B., Hobbs, R., Hooper, D., Lawton, J., Sala, O., Tilman, D. (1997) *Biotic control over the functioning ecosystems*, Science, vol. 277, no. 5325, pp. 500-504. DOI: http://dx.doi.org/10.1126/science.277.5325.500

Cobb, C., Halstead, E., Rowe, J. (1995) *The Genuine Progress Indicator – summary of data and methodology*, Washington D.C.: Redefining progress.

Costanza, R. (2000a) *The dynamics of the ecological footprint concept*, Ecological economics, vol. 32, p. 341-345.

Costanza, R. (2000b) *Social goals and the valuation of ecosystem services*, Ecosystems, vol. 3, no. 1, pp. 4-10. DOI: http://dx.doi.org/10.1007/s100210000002

Constanza, R., Daly, H. (1992) *Natural capital and sustainable development*, Conservation Biology, vol. 6, no. 1, pp. 37-46. DOI: http://dx.doi.org/10.1046/j.1523-1739.1992.610037.x

Costanza, R., Folke, C. (1997) *Valuing ecosystem services with efficiency, fairness, and sustainability as goals*, in Daily G. (ed.) *Nature's services. Societal dependence on natural ecosystems*, pp. 49-71, Washington D.C.: Island Press.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelp, J., Raskin, R.G., Sutton, P., van den Belt, M. (1997) *The value of the world's ecosystem services and natural capital*, Nature, vol. 387, pp. 253-260. DOI: http://dx.doi.org/10.1038/387253a0

Daily, G., Söderqvist, T., Aniyar, S., Arrow, K., Dasgupta, P., Ehrlich, P., Folke, C., Jannson, A., Jannson, B.O., Kautsky, N., Levin, S., Lubchenco, J., Mäler, K.G., Simpson, D., Starrett, D., Tilman, D., Walker, B. (2000) *The value of nature and the nature of value*, Science, vol. 289, no. 5478, pp. 395-396. DOI: http://dx.doi.org/10.1126/science.289.5478.395

Daly, H. (1992) *Steady-state economics, with new essays,* Second Edition. London: Earthscan.

Daly, H. (2005) *Economics in a full world*, Scientific American, vol. 293, no. 3, pp. 100-107. DOI: http://dx.doi.org/10.1038/scientificamerican0905-100

Daly, H., Cobb, J. Jr. (1989) *For the common good,* Boston: Beacon Press.

EIA (2013) U.S. Energy Information Administration statistics, available online at http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=44&pid=44&aid=2&cid=r3, &syid=2007&eyid=2008&unit=QBTU, site last accessed 07.11.2013

Ekins, P. (2003) *Identifying critical natural capital*. *Conclusions about critical natural capital*, Ecological Economics, vol. 44, pp. 277-292. DOI: http://dx.doi.org/10.1016/S0921-8009(02)00278-1

Eurostat (2013) Eurostat database query, available online at http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&language=en&pcode=tps00003&plugin=1, site last accessed 07.11.2013

Giuliani, M. V. (2003) *Theory of attachment and place attachment*, in Bones, M., Lee, T., Bonaiuto M. (eds.) *Psychological theories for environmental issues*, pp. 137-170, Aldershot: Ashgate Publishing.

Heal, G. (2000) *Valuing ecosystem services*, Ecosystems, vol. 3, no. 1, pp. 24-30. DOI: http://dx.doi.org/10.1007/s100210000006

Heal, G. (2004) *Economics of biodiversity. An introduction*, Resource and energy economics, vol. 26, no. 2, pp. 105-114. DOI: http://dx.doi.org/10.1016/j.reseneeco.2003.11.002

Hidalgo, C., Hernandez, B. (2001) *Place attachment: conceptual and empirical questions*, Journal of Environmental Psychology, vol. 21, no. 3, pp. 273-281. DOI: http://dx.doi.org/10.1006/jevp.2001.0221

Mayer, S. & Frantz, C. (2004) *The connectedness to nature scale: a measure of individual's feeling in community with nature*, Journal of Environmental Psychology, vol. 24 pp. 503-

515.

Myers, N. (1997) *Biodiversity's genetic library*, in Daily G. (ed.) *Nature's services: Societal dependence on natural ecosystems*, pp. 255-275, Washington D.C.: Island Press.

Proshansky, H., Fabian, A., Kaminoff, R. (1983) *Place-identity: physical world socialization of the self*, Journal of Environmental Psychology, vol. 3, no. 1, pp. 57-83. DOI: http://dx.doi.org/10.1016/S0272-4944(83)80021-8

Rees, W.E. (2000) *Eco-footprint analysis: merits and brickbats*, Ecological Economics, vol. 32, pp. 371-374.

Rees, W.E., Wackernagel, M. (1994) *Ecological footprints and appropriated carrying capacity: Measuring the natural capital requirements of the human economy*, in Jansson, A.M., Hammer, M., Folke, C. and Costanza R. (eds.) *Investing in natural capital: The ecological economics to sustainability*, pp. 362-392, Washington D.C.: Island Press.

Schultz, W. (2002) *Inclusion with nature: The psychology of human-nature relations*, in Schmuck P., Schultz W.P. (eds.) *Psychology of sustainable development,* pp. 61-79, Dordrecht: Kluwer Academy Publishers.

Schultz, W., Shriver, C., Tabanico, J. & Khazian, A. (2004) *Implicit connections with nature*, Journal of Environmental Psychology, vol. 24, no. 1, pp. 31-42. DOI: http://dx.doi.org/10.1016/S0272-4944(03)00022-7

Tilman, D., Downing, J. (1994) *Biodiversity and stability in grasslands*, Nature, vol. 367, pp. 363-365. DOI: http://dx.doi.org/10.1038/367363a0

Tilman, D., Wedin, D., Knops, J. (1996) *Productivity and sustainability influenced by biodiversity in grassland ecosystems*, Nature, vol. 379, pp. 718-720. DOI: http://dx.doi.org/10.1038/379718a0

Tilman, D., Knops, J., Wedin, D., Reich, P., Ritchie, M., Siemann, E. (1997) *The influence of functional diversity and composition on ecosystem processes*, Science, vol. 277, no. 5330, pp. 1300-1302. DOI: http://dx.doi.org/10.1126/science.277.5330.1300

Tilman, D., Reich, P., Knops, J. (2006) *Biodiversity and ecosystem stability in a decade-long grassland experiment*, Nature, vol. 441, pp. 629-632. DOI: http://dx.doi.org/10.1038/nature04742

UNDP (1996) United Nations Development Program Human Development Report, Oxford: Oxford University Press.