Can biodiversity, human wellbeing and sustainable development indicators be linked?

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Abstract: A mission to reduce the rate of loss of biodiversity as a contribution to poverty reduction was agreed as part of the Strategic Plan for the Convention on Biological Diversity, adopted by the Conference of the Parties in 2002. As 2010 draws to a close it is clear that this target will not be met. To continue and build on momentum generated by the 2010 target, the conservation community has been discussing a potential post-2010 framework that again includes explicit reference to the link between human wellbeing and conservation, and also considers the links with human wellbeing and sustainable development. Given this agreement, we reviewed several human wellbeing and sustainable development indicators compared to existing biodiversity status and trends indicators to determine if clear correlations can be found that could be used to track progress in a new framework. We undertook this review at both the global and continental levels. The indicators for protected area and forest cover showed significant positive correlation across all continents. We found a significant negative correlation between changes in protected area (PA) cover and tonnage of greenhouse gas emissions released (GHGe) between 1990 and 2005 for all the continents. At the global level we found no other correlation across the indicators reviewed. However, we found that correlations between the biodiversity and human wellbeing and sustainable development indicators varied across continents. As the only indicators for which global level correlations exist, we suggest that either protected area coverage or forest cover may be relevant biodiversity indicators for global analyses of biodiversity-human wellbeing or sustainable development relationships, and that the relationship between protected area cover and greenhouse gases could be one indicator for links between biodiversity and sustainable development. More research is needed to better understand factors involved in the relationships between biodiversity, human wellbeing and sustainable development, and to identify useful indicators of these linkages at global or continental level. In the meantime, the challenges presented by demonstrating these links should not delay urgently needed conservation actions.

Keywords: 2010 targets, assessment, human wellbeing, Indicators, sustainable development.

INTRODUCTION

In recognition of the urgency of the biodiversity crisis, the 2010 biodiversity target "*…to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth"* was adopted by the Sixth Conference of the Parties to the Convention on Biological Diversity (CBD; The Hague, Netherlands, April 2002) as part of the Convention's Strategic Plan (CBD 2002). A similar target was adopted at several other fora

Abbreviations: ANS - Adjusted Net Savings; CBD - Convention on Biological Diversity; ECOPRINT - Ecological Footprint; FAO - Food and Agriculture Organization of the United Nations; GDP - Gross Domestic Product; GHGe - Greenhouse gas emissions; HDI - Human Development Index; IUCN - International Union for Conservation of Nature; NMP - Numbers of malnourished people; UNDP - United Nations Development Programme; UNEP - United Nations Environment Programme from 2002 to 2007, including the Johannesburg Plan of Action and the Millennium Development Goals. Through such targets the global community has recognized a link between biodiversity conservation, human wellbeing and sustainable development.

Although the specific formulation differs for each, the 2010 biodiversity target is one of the most relevant international tools to draw attention to the urgent situation for biodiversity globally, and to catalyze action to conserve nature, which underpins human wellbeing (IUCN 2009). Nevertheless, despite the increased awareness and energy invested in biodiversity conservation as a result of the 2010 biodiversity target, the target itself will not be met (Secretariat of the CBD, 2010). The rate of biodiversity loss has not measurably reduced, the world has more poor people than ever and economic development is being achieved at the price of measurable climate change. Action is still required to improve environmental governance, ensure adequate investment in environmental management, promote full engagement of all stakeholders in conservation and provide for better long term monitoring of biodiversity.

In October 2010, the CBD held its 10th Conference of the Parties at which a new strategic plan and associated post-2010 biodiversity conservation framework of targets was adopted. Discussions are underway to articulate a post-2010 framework of indicators within the next Strategic Plan of the CBD, including the need to reinforce biodiversity's role in sustainable development and poverty reduction, as specified in the 2010 target. Ideally, any new framework should build on the lessons learned and reinforce the positive aspects of the previous framework. With respect to the indicators, the lessons learned from the 2010 target indicator framework include the fact that "The framework does not explicitly include development/social indicators to measure directly the impact of biodiversity loss on development and poverty reduction. As the full wording of the target includes specific reference to the link between biodiversity and development/poverty reduction, inclusion of relevant indicators is essential to highlight these links between impact of biodiversity loss or conservation successes and development" (IUCN 2009).

Human wellbeing has been defined, within the conceptual framework of the Millennium Ecosystem Assessment (MA) as comprising access to basic materials for life, health, good social relations, security and freedom of choice and action (MA 2003). Sustainable development has been defined, by the Brundtland Commission as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN 1987). Using these definitions, human wellbeing focuses on the current situation while sustainable development includes future considerations.

The role of biodiversity in supporting human wellbeing and sustainable development is multi-faceted and has been described through concepts including that of ecosystem services (Daily 1997; MA 2005). Many models have graphically represented the relationship between people and nature (MA 2005; Diaz et al. 2006; McNeely & Mainka 2009). Any post-2010 framework could consider including indicators that directly evaluate changes in human wellbeing or sustainable development against indicators of biodiversity status and trends. A cost effective and efficient approach to monitoring progress would draw on indicators from among those that are already being measured though new indicators may need to be developed to fully assess the links.

This paper reviews the correlation among a selection of national level indicators of biodiversity status and compares them to several existing indicators for human wellbeing and sustainable development. Any resulting correlation could be useful to inform any post-2010 biodiversity conservation framework as well as any future research agenda for monitoring progress on human wellbeing, sustainable development and biodiversity conservation.

MATERIALS AND METHODS

Challenges in linking biodiversity indicators with human wellbeing and sustainable development indicators include the need to have a common spatial basis for measurement and also the need to have enough data points to make the comparisons. For time series comparisons, we also needed indicators that have been measured over long enough periods of time.

With respect to human wellbeing, standard indices are generally available at national level and include the Human Development Index (HDI) of UNDP and the numbers of malnourished people (NMP) as reported by the FAO. For sustainable development, the Adjusted Net Savings (ANS) of the World Bank, and the Ecological Footprint (ECOPRINT) of the Global Footprint Network, along with greenhouse gas emissions (GHGe) are also currently being regularly assessed at national level. Therefore, biodiversity indicators assessed at national level were chosen for this review.

Biodiversity status indicators have been under development within the framework of the CBD's 2010 framework and the Biodiversity Indicators Partnership, a consortium of 28 partners collaborating to further develop and promote indicators for the consistent monitoring and assessment of biodiversity. Out of the 22 indicators selected, several still need either development or more complete data sets and hence will be of limited use in assessing progress towards the 2010 target. For the purposes of comparison on a national basis, one of the 22 CBD indicators (protected area coverage) was available and for this review we supplemented it with other biodiversity indicators that were already available, including the numbers of threatened endemic species (biodiversity at species level), forest area cover (biodiversity at ecosystem level) and national biocapacity (biodiversity at ecosystem service level).

Detailed description of the indicators used are as follows

Biodiversity status and trend indicators

The following were used in this review:

(i) Percentage of endemic species per country that are threatened (Threatened Endemic Species; TES) - This includes data from the 2000 and 2004 IUCN Red List of Threatened Species (www.iucnredlist.org). It is an indicator of level of threat to the species most in need of conservation attention to prevent their global extinction and includes data on mammals, birds, amphibians, freshwater crabs, reef-forming corals, conifers, and cycads from 247 countries and territories. As no data on threatened endemics at national level are available for 2005, data for 2004 were used. Threat status for species included in this analysis are unlikely to change within one year and therefore the 2004 data should represent a fair comparison with human well being and sustainable development indicators for 2005 (Red list Officer (C. Hilton-Taylor, pers. comm.)).

(ii) Land area gazetted as protected areas (PA coverage) - Data on terrestrial and marine protected areas for 1990, 2000 and 2005 was downloaded from the MDG indicator database (http://millenniumindicators.un.org/unsd/mdg/Data.aspx) and included information from 218 countries and territories within which the analysis for terrestrial and marine protected areas was conducted.

(iii) Land area with forest cover (Forest Cover) - Data from the Global Forest Resources Assessments from 1990, 2000 and 2005 (ftp://ftp.fao.org/docrep/fao/008/A0400E/A0400E14.pdf) included information from 207 countries and territories. Forest area was determined both by the presence of trees and the absence of other predominant land uses, including land spanning more than 0.5 hectares with trees higher than 5m and a canopy cover of more than 10%, or trees able to reach these thresholds, such as areas under reforestation and areas temporarily unstocked but expected to regenerate.

(iv) Biocapacity - The Global Footprint Network (www.footprintnetwork.com) assesses, at national level, the capacity of ecosystems to produce useful biological materials and to absorb waste materials generated by humans, using current management schemes and extraction technologies. Data for 1999 and 2005 were used in this analysis. As no data were available for 2000, the 1999 data were used as proxies for the 2000. The biocapacity of each country is expressed in units of global hectares per capita with a global hectare referring to the amount of biologically productive land and water available.

Human Well Being Status and Trend Indicators (HWB Indicators)

(i) Human Development Index (HDI) – The Human Development Index (HDI) is a composite index that combines measures of life expectancy (life expectancy at birth), education (adult literacy rate and education enrollment levels) and living standards (GDP per capita). HDI is calculated on a scale from 0-1 with values up to 0.500 representing low development, 0.501-0.799 representing medium development and values above 0.800 representing high development. Data for 1990, 2000 and 2005 were used in this analysis.

(ii) Numbers of undernourished people (NMP) – As reported by the FAO, undernourishment refers to "the condition of people whose dietary energy consumption is continuously below a minimum dietary energy requirement for maintaining a healthy life and carrying out a light physical activity with an acceptable minimum body-weight for attained-height". Data for the number of malnourished people indicator is organized for two year interval, and for this analysis we used the values for 1990-1992, 2000-2002 and 2004-2006 as proxy for the years 1990, 2000 and 2005.

Sustainable Development Status and Trend Indicators (SD Indicators)

(i) Adjusted Net Savings (ANS) – Adjusted Net Savings (ANS) is an aggregate indicator, from the World Bank, that attempts to quantify the various forms of capital that a country possesses and then assess the net value of that capital. This is a composite index calculated from standard national accounting measures of gross national savings adjusted according to educational expenditures, depreciation, mineral depletion, energy depletion, and damage from carbon dioxide and fine particulate emissions. Positive ANS values imply sustainability while negative values imply countries living beyond their means. Data for 1990, 2000 and 2005 were used in this study and are available http://databank.worldbank.org) for an average of 90-100 countries since 1990.

(ii) Ecological Footprint (ECOPRINT) – Ecological footprints are measures of the human demands on biological capacity to sustain consumption across fisheries, cropland, forests, land use/urban and carbon. For the years 2000 and 2005 data are available (http://www.globalfootprintnetwork.com) for 150 countries.

(iii) Greenhouse gas emissions (GHGe) - Data for total emissions of carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexaflouride, and including land use change for 185 countries and territories for 1990, 2000 and 2005 were obtained from the World Resources Institute's Climate Analysis Indicators Tool (http://cait.wri.org).

As single point data may reflect stochastic events as opposed to general trends, we sought to review at least two data points per country. Unfortunately such data does not exist for all the indicators, thus we limited our analyses to indicators for which data points in the year 2000 and 2005 were available. This meant that we had at least two data points per country for an indicator for each comparison.

We also attempted to assess correlations, through correlation matrices, in changes over a 15 year period of the indicators for which such data was available. Data was available for 1990 and 2005 for forest cover, protected area coverage, HDI, NMP, ANS and GHGe. Countries were included in these analyses if data points were available for both years.

Data analyses were done on global and continental levels. We grouped countries for which the indicators were available into continents following the standard UN regional classifications (http://millenniumindicators.un.org/unsd/methods/m49/m49regin.htm) consisting of Africa, Asia, Europe, North and Central America and the Caribbean (NCAC), South America and the Oceania.

All analyses were conducted with the R 2.10.1 statistical software (R core Team 2009). We examined the correlation between biodiversity indicators using the Pearson product-moment correlation and tested for the biodiversity indicators across continents using analyses of covariance (ANCOVA) followed by Tukeys' Honest Significant test ($p > 0.05$). Based on Pearson product-moment coefficient correlation matrix, we examined the correlations between the biodiversity and human well being and sustainable development indicators. We report only significant correction coefficients computed from more than ten data points. We also emphasize here that correlation should not be taken to mean causality; it does imply some relationship between the two parameters, including relationships involving an external but common factor.

RESULTS

Biodiversity indicators

Among the biodiversity indicators, only forest cover and PA coverage were correlated across all continents. Only an estimated 13.5% of global forests are included within IUCN Category 1-VI protected areas (Schmitt et al. 2009) so this correlation is unlikely to be simply because forest ecosystems represent the majority of protected area systems. We also found a significant difference between some of the biodiversity indicators at continental level ($p < 0.001$) under consideration. The TES per country was positively correlated with forest cover only for Africa. We found significant correlations across changes in biodiversity indicators between 1990 and 2005. There was a positive correlation between change from 1990-2005 in percentage of PA cover and percentage forest cover in South America, while negative correlation was found for NCAC and Oceania. (Table 1).

Correlations across Biodiversity, Human Wellbeing and Sustainable Development Indicators

At the global level, no correlation across either HWB and biodiversity indicators or SD and biodiversity indicators was found. At continental level, some other patterns across these indicators did emerge (Table 2).

From the perspective of biodiversity indicators, the %TES per country showed a positive correlation with NMP in Africa, Asia and South America and with ECOPRINT in Asia. Forest cover was negatively correlated with HDI and ANS in Africa. Positive correlations were seen for forest cover and NMP and GHGe in Africa, Asia and South America and with GHGe in Europe. Forest cover was positively correlated with HDI in North America. PA coverage showed similar correlations to that for forest cover with the exception of no correlation with ANS for Africa or with GHGe for South America. Biocapacity showed no correlation with either of the HWB indicators but did show a negative correlation with ANS in both

Table 1. Correlation within biodiversity indicators across continents. Only significant correlations ($p < 0.05$) are included.

	%TES	Forest Cover	PA coverage	Biocapacity	Change in Forest cover 1990-2005	Change in PA cover 1990-2005
%TES		1				
Forest Cover	1		1,2,3,4,5,6			
PA coverage		1,2,3,4,5,6				
Biocapacity						
Change in Forest cover 1990-2005						4, -5, -6
Change in PA cover 1990-2005					4, -5, -6	

1 - Africa; 2 - Europe; 3 - Asia; 4 - South America; 5 - NCAC; 6 - Oceania.
"-" a negative significant correlation between the indicators for the continent being compared

Table 2. Correlation between biodiversity and HWB and SD indicators across the continents. Only significant correlations ($p < 0.05$) are included.

Biodiversity Indicators		HWB Indicators		SD Indicators		
		HDI	NMP	ANS	ECOPRINT	GHGe
	% TES		1, 3, 4		3	
	Forest Cover	-1,5	1, 3, 4	-1		1, 2, 3, 4
	PA coverage	-1,5	1, 3, 4			1, 2, 3
	Biocapacity			-1, -4	2, 4	

1 - Africa; 2 - Europe; 3 - Asia; 4 - South America; 5 - NCAC; 6 - Oceania.
"-" a negative significant correlation between the indicators for the continent being compared

Africa and South America and a positive correlation with ECOPRINT in Europe and South America.

Correlations across Changes in Biodiversity, Human Wellbeing and Sustainable Development Indicators from 1990-2005

Change in forest cover between 1990-2005 correlated negatively with HDI in Europe and NCAC, and with NMP in Africa, Asia and South America. Forest cover also correlated negatively with GHGe in NCAC and Oceania but positively for Africa (Table 3). Over the same period, we also found that change in PA cover correlated negatively with HDI only for NCAC and with NMP for Asia and South America. Changes in PA cover correlated positively with ANS in Europe and Asia. We found a significant negative correlation between PA cover and GHGe for all the continents (Table 3).

DISCUSSION

The 2010 biodiversity target included an explicit reference to the contributions of biodiversity to ".. *poverty alleviation and to the benefit of all life on earth*". It is probable that any post-2010 framework chosen by Parties will echo this contribution and continue to emphasize the importance of biodiversity to people. Any targets that are adopted that include this aspect of biodiversity's role should, therefore, include measurements of human wellbeing and/or sustainable development that parallel measurements of status and trends in biodiversity. However, the usefulness of including such HWB or SD indicators in a post-2010 biodiversity framework will depend on whether the selected indicators have some correlation with indicators for biodiversity.

Correlation among biodiversity indicators

One of the important results from our preliminary data analyses is that correlation among the biodiversity indicators is not necessarily global and do differ between continents. This finding has implications for studies that use these indicators for global comparison of biodiversity-development relationships and highlights the need to include consideration of continental differences in natural resources distribution, socio-cultural, political and economic factors when considering links across biodiversity and HWB or SD. For example, we found a positive correlation between TES and forest cover in Africa. A positive correlation may result, generally speaking, because more species are located in larger areas although the specific relationship, as defined by species/area curves may change depending on local conditions. Therefore, areas with greater numbers of species will likely have more potentially threatened species as well. Why this threatened endemic species/area relationship did not apply beyond Africa is an interesting question. One factor that might play a role would be different percent total forest cover. The 2005 Global Forest Resources Assessment (FAO 2006) reports that Africa had 21.4% forest cover compared to 18.5% for Asia, 44.3% for Europe, 47.7% for South America and 24.3% for Oceania. However, if lower continental percentage of forest cover (global average ~30%; FAO 2005) was a factor then Asia and Oceania should also show no correlation.

We did not find any correlation between biocapacity and other biodiversity indicators across any of the continents. This may be because biocapacity, as a measure of ecosystem capacity to deliver services, considers only "biologically productive land" and does not include what are deemed to be "non-productive and marginal areas" such as arid regions, open oceans, the

Table 3. Correlation between changes in biodiversity and HWB and SD indicators across the continents from 1990-2005. Only significant correlations ($p < 0.05$) are included.

Changes in biodiversity indicators		Changes in HWB Indicators		Changes in SD Indicators	
		HDI 1990-2005	NMP 1990-2005	ANS 1990-2005	GHGe 1990-2005
	Forest cover 1990-2005	-2,-5	-1,-3,-4		1,-5,-6
	PA cover 1990-2005	-5	-3,-4	2, 3	-1,-2,-3,-4,-5,-6

1 - Africa; 2 - Europe; 3 - Asia; 4 - South America; 5 - NCAC; 6 - Oceania.
"-" a negative significant correlation between the indicators for the continent being compared

cryosphere and other low-productivity surfaces. Areas producing biomass that is not of use to humans are also not included. Therefore, in 2003, for example, biocapacity was a measure of biodiversity for only about one quarter of the planet's surface (Kitzes et al. 2007) and perhaps limiting its use as a more general indicator of biodiversity status.

Interestingly, while PA cover and forest cover were correlated across all continents using the 2000/2005 data, changes in those parameters over 15 years were not correlated globally but showed a positive correlation for South America and a negative correlation for NCAC and Oceania. This result could suggest that, in these continents, proportional representation of forests within protected areas has varied differently during this 15 year period. However, the differences may also be related to the FAO data used. As described by Hansen et al. (2010), the FAO provides the premier global database on forest cover but the data have several features that should be considered in interpreting analyses. These include (i) different methods to quantify forest change among all countries; (ii) the definition of "forest" is based on land use instead of land cover; (iii) forest area changes are reported only as net values; and (iv) forest definitions used in successive reports have changed over time.

Human Wellbeing and Sustainable Development Indicators and Biodiversity Indicators

No correlation was found, at global level, for any of the biodiversity indicators across either HWB or SD indicators, nor was any correlation found for changes over 15 years for the selected HWB or SD indicators. There could be several reasons for this result. First, the link between sustainable development/human wellbeing is confounded by the multitude of other influences beyond biodiversity (for example, economic issues such as perverse incentives) and the complex interactions between these other influences may not be yet well enough understood to be measured. Second, several of the sustainable development indicators used today (including those in this study) do not fully integrate biodiversity into the calculations, as noted above in the individual indicator descriptions. Third, conservation happens at a local level and local impacts and conservation successes may not be reflected in a national indicator or at global level. Fourth, national level indicators do not always include impacts from external sources. With respect to changes over time, as noted above regarding forest data, changes in definitions and scope over time can confound synthesis and analysis of data collected across many sources. In addition, there is likely a time lag between changes in biodiversity status and measurable impacts on human wellbeing and vice versa.

The negative correlation seen in Africa across HDI and two of the biodiversity indicators and ANS and forest cover is also interesting. Lower forest cover or PA coverage accompanied by increasing HDI suggests that Africa, as compared to other continents, continues to be heavily reliant on using natural resources to support HWB. The negative correlation for Africa across ANS and both forest cover and biocapacity is counterintuitive, since ANS purports to measure national 'savings' including natural capital, yet the correlation in Africa across forest cover and biocapacity shows that as these values decrease (meaning lower natural capital) the ANS value increases. The positive correlation between changes in PA coverage and ANS in Europe and Asia, however, does support the concept that protected areas represent an investment in national natural capital and wealth.

Based on this review, a comparison of the national level biodiversity indices across either HWB or SD indices used here showed no correlations at global level along with some correlations at continental level, with several of the latter being difficult to explain. However, this exercise was far from comprehensive and continuing to explore other HWB or SD indicators, and combinations thereof, may provide different results. For example, Mikkelson et al. (2007) conclude that including indicators for economic inequality, such as the GINI index, can significantly improve prediction of biodiversity loss, although the number of countries reviewed was limited both by availability of biodiversity data and time-relevant GINI measurements. In addition, comparison of changes in indicators across different time frames, to allow for delays in impacts to be measured, may also provide useful information.

Another lesson gained from this exercise to demonstrate or monitor the relationships between biodiversity and HWB or SD, is that some of the indicators commonly used to assess progress in human wellbeing and sustainable development may not be telling us what we really need to know. For example, 88% of countries are in medium or high development for HDI but neither the potential cost nor longer term implications of that development on biodiversity and ecosystem services appear to be reflected in the indicator. As noted above, ANS which measures national 'savings' appeared to increase with decreasing biodiversity in at least one continent. Similarly, the Ecological Footprint is tracking demand on biological capacity yet demonstrated few correlations with any of the biodiversity indicators, which should provide information on the status of the raw material providing that capacity in this review.

As the conservation community debates the many options for the next CBD Strategic Plan, the formulation of any targets within that Plan should consider the challenges faced by measuring the links between biodiversity conservation and supporting human well being and poverty reduction. McNeely (2009) notes that the 2010 framework is stated in a way that makes assumptions about the link between biodiversity conservation and poverty reduction that is "…perhaps best regarded as an hypothesis that is likely to show considerable variability at different geographical scales". These challenges notwithstanding, should the Parties decide to include the role of biodiversity conservation in supporting human well being in a future framework for action, any strong correlations resulting from a comparison across biodiversity and development indicators would be useful to identify data that should or could be highlighted therein. No matter which way Parties choose to include a link with human wellbeing and poverty reduction in the next framework, the inability to explicitly make the link through indicators should not stop or delay biodiversity conservation actions that are urgently needed both to support human wellbeing and biodiversity itself.

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