Accounting for Sustainable Development:
Complementary Monetary and Biophysical Approaches

Mathis Wackernagel,[i] Kirk Hamilton,[ii] Jonathan Loh,[iii] and Jerome Sayre[iv]

Prepared for the *OECD Roundtable on Sustainable Development*

November 21, 2001

Summary

This Working Paper explains the utility of combining monetary accounts with biophysical accounts to track progress towards sustainability.

Monetary accounts capture information on the assets that contribute to a nation's wealth, on the assumption that safeguarding wealth is indispensable for maintaining economic vitality. Biophysical accounts consider the uses of domestic and global natural capital, on the assumption that maintaining economic vitality depends on basic ecological services such as renewable and non-renewable resources, waste absorption, and stable climate conditions.

Used in tandem, these two measurements provide policymakers with detailed intelligence on economic and ecological viability. Such an approach can also illuminate the relationship between national and global sustainability, and identify policy responses.

1. Protecting the Wealth of Nations

When the Brundtland Commission offered its famous definition of sustainable development—"to meet the needs of the present without compromising the ability of future generations to meet their own needs"[v]—it presented several challenges to policy-makers. Not least among these is the question: how do we measure progress towards sustainable development?

In the wake of the Brundtland Commission's report sustainable development has been interpreted as a three dimensional concept which combines economic, social, and ecological perspectives. The foundation for this concept is a set of assets that underpin and support the development process. These may be divided into the following broad categories:

- *Physical capital:* economic assets such as buildings, machines and infrastructure that are the economist's usual concern.

- *Social capital:* people's skills and abilities as well as the institutions, relationships, and norms that shape the quality and quantity of a society's social interactions.

- *Natural capital:* natural resources, both commercial and non-commercial, and ecological services which provide the requirements for life, including food, water, energy, fibers, waste assimilation, climate stabilization, and other life-support services.

If the per capita value of these assets declines, economists conclude that future social well-being will be less than current well-being[vi]—a development path that is not sustainable. Pearce *et al.*[vii] call this *weak* sustainability. While this represents the core of sustainability, this requirement is limited in practice by the difficulty of determining the values of these assets. Monetary values can be assigned for assets traded on a market such as timber or cereals. But for other natural assets, determining an accurate price can be elusive. More importantly, even if values can be determined for natural capital assets, they may not signal that certain ecological limits are being breached in an irreversible manner, with serious consequences for human welfare.

Pearce *et al.* offer a way out of this conundrum by introducing the concept of *strong* sustainability. *Strong* sustainability recognizes that there are natural assets (which are frequently global) that do not have substitutes—for example the ozone layer—whose loss would entail serious harm to human beings and nature. *Strong* sustainability therefore requires that some critical amount of the non-substitutable natural capital be preserved, independent of any increases in value of other social or physical assets.

Any meaningful analysis of sustainability would therefore need to pay attention to both concepts of sustainability. This can be accomplished by complementing purely monetary assessments (measuring in dollars or Euros), which are useful for documenting core aspects of weak sustainability, with biophysical ones (measuring in tones, hectares or joules) effective for tracking strong sustainability.[viii]

2. Using Monetary and Biophysical Accounts in Tandem

To illustrate the usefulness of combining monetary and biophysical accounts for tracking progress towards sustainable development, this Working Paper draws together two particular approaches which are currently under active development.

2.1 Monetary asset accounts

Monetary asset accounts analyze to what extent the wealth of a nation is increasing or decreasing per citizen, [ix] thereby informing about progress on 'weak sustainability.' Table 1 highlights the results of such monetary accounting in per capita terms for selected countries. It details first the components of depletion and degradation of the environment—the value of depletion of minerals and mineral fuels, the value of *net* depletion of forests (i.e. where harvest rates exceed natural growth rates), and the global damage incurred when CO_2 is emitted. The sum of these figures is a crude monetary measure of depletion and degradation. This sum is juxtaposed with figures on net domestic saving—the amount of GDP that is not consumed by households and governments, less the value of depreciation of produced assets.

Comparing net saving to total depletion and damage provides an initial assessment of sustainability. It answers the question of whether countries are depleting their natural assets faster than they are building up produced assets. It provides a less than complete picture, however. Some elements of what the national GDP accounts consider to be consumption, such as education expenditures, are clearly not; some natural assets, such as soils, are not accounted for in the World Bank figures owing to problems of data availability, as well as analytical issues.

Table 1: Monetary asset accounts: Results from 6 selected countries (measured in 1997 US dollars, 1997 data). The table provides estimates of annual change in value of some main national assets, including the impact of demographic growth on per capita wealth.

Depletion, damage, and saving effort — Selected countries, in 1997$ per capita (1997 data)						
	Australia	Chile	Indonesia	Netherlands	Pakistan	Zimbabwe
Mineral and fuel depletion	-411	-335	-61	-26	-9	-24
Net forest depletion	0	0	-6	0	-7	-3
CO2 damages	-94	-22	-7	-57	-4	..
Total depletion and damage	-505	-358	-73	-83	-20	-26
Net domestic saving	2108	678	237	4041	15	30
Effect of population growth	-3461	-915	-196	-1196	-170	-207

Source: World Bank estimates, derived from World Bank (1999) and Hamilton (2000).[x]

A major omission in the comparison of net saving to total depletion and damage is the effect of population growth. This is shown as the final entry in Table 1. To take Zimbabwe as an example, the suggestion from the table is that net wealth actually increased by $4 per capita in 1997. However, this somewhat larger sum of national wealth has to be shared among a Zimbabwean population that has grown by 2.1% over the course of the year, which produces a decline in wealth per capita of $207. The intuitive conclusion to be drawn from this result is that the percentage increase in total wealth was substantially less than the percentage increase in total population.

2.2 Biophysical accounts of natural capital

Biophysical natural capital accounts measure sustainability by evaluating to what extent humanity's demands on the biosphere, in terms of renewable and non-renewable resource consumption and waste production, exceed nature's capacity to renew itself.[xi] They are derived from material accounts[xii] and the biological productivity[xiii] literature and assess, for any given activity, the biologically productive area required to produce the resources and to absorb the waste of that activity, using prevailing technology. [xiv] Such biophysical accounts, therefore, provide a measure of strong sustainability.

Table 2 provides an outline of the results, providing key data for the same set of nations as in Table 1. The first section of the accounts captures the biological productivity of the nation—the supply of ecological services within its own borders. The second section documents the nation's uses of natural capital in various categories—its demand on ecological services. All results are presented in the same common units: global hectares—standardized hectares with world-average biomass productivity. [xv] As Table 2 shows, in some cases nations' demand on nature is smaller than their domestic supply, and in some cases it is larger.

It is worth noting that a distinct advantage of the biophysical approach is that it offers a broader, more global perspective on sustainability. This is important, because many of the environment-related issues of sustainability do not respect national borders. In this context, Table 2 sheds light on some of the biophysical difficulties inherent in measuring sustainable development. According to this analysis, the Earth provides 2.2 hectares of bioproductive space per world inhabitant. In contrast, the average consumption of the world citizen requires 2.8 global hectares, or 1.3 times more. This means that, currently, it takes the biosphere 1.3 years to regenerate what humanity consumes within one year. CO_2 is responsible for half of the impact: it would take about 1.4 global hectares per person to either sequester the excess CO_2 or produce the same energy with plant matter. As demand (consumption) exceeds supply (biocapacity), the world's natural capital is being depleted. Examples are deforestation, freshwater scarcity, fisheries decline, or CO_2 accumulation in the atmosphere.

For countries, the accounts can reveal specific vulnerabilities. Take the example of Australia. This country is endowed with 42 hectares of land per inhabitant, of which 34 are biologically productive. This biocapacity corresponds to merely 9.3 global hectares per Australian, primarily due to water scarcity. In contrast, Australia's vast transportation infrastructure, large share of coal energy, and high consumption of animal products boosts its demand on nature to an equivalent of 8.5 global hectares per Australian, slightly less than the 9.3 global hectares of biocapacity. It is worth emphasizing that this perspective does not fully take into account the impact of international trade and the way in which this might alter the overall picture.

The same perspective applied to Zimbabwe reveals a somewhat different picture. For this country, the accounts show 3.5 hectares of land per Zimbabwean. However, due to water scarcity and poor soils, the biomass productivity of these hectares is low. Hence these 3.5 hectares per person correspond to only 0.7 global hectares per Zimbabwean—these are hectares with global average bioproductivity. This biocapacity is half of what is required for producing the resources and absorbing the waste associated with the consumption of an average Zimbabwean. A significant portion of the difference between the available biocapacity and the Zimbabwean use of biocapacity stems from the overexploitation of domestic forest resources.

Table 2: Biophysical natural capital accounts: Results from 6 selected countries and the world (measured mostly in 'global hectares', 1996 data). The upper part of the table provides estimates of the biological capacity available in the country by adjusting the land and sea area of a country for its biomass productivity. Hence the biocapacity can be expressed in the common units of 'global hectares.' The lower part of the table documents the use of biocapacity in various subcategories. (1999 data will be available by June 2001).

	Australia	Chile	Indonesia	Pakistan	Netherlands	Zimbabwe	World
Population (in millions)	18	14	200	140	16	11	5,745
Supply							
Physical land area (ha/cap)	42.3	5.2	0.9	0.6	0.2	3.5	2.3
Multiply by % of land bioproductive (%)	80%	44%	88%	39%	85%	75%	72%
Add physical area of bioproductive sea (ha/cap)	8.1	5.2	0.9	0.1	0.2	0.0	0.6
= Total bioproductive area (ha/cap)	41.9	7.5	1.7	0.3	0.4	2.6	2.2
Multiply by relative bioproductivity***** (-)	0.22	0.27	1.90	2.31	6.39	0.26	1.00
*Total biocapacity supply (global ha******/cap)*	***9.3***	***2.0***	***3.2***	***0.7***	***2.3***	***0.7***	***2.2***
Demand (in global hectares** per capita)							
Agriculture	2.6	1.2	0.6	0.7	2.1	0.7	1.0
Forest products	0.6	0.6	0.3	0.1	0.5	0.3	0.3
Fish products	0.06	0.11	0.04	0.00	0.05	0.01	0.04
Built-up area	0.4	0.1	0.1	0.0	0.3	0.0	0.1
CO_2 emissions	4.8	1.1	0.4	0.3	3.7	0.4	1.4
*Total biocapacity demand (global ha******/cap)*	***8.5***	***3.1***	***1.4***	***1.1***	***6.6***	***1.4***	***2.8***

Source: Redefining Progress, based on primary data from UN agencies[xvi]

Definitions: ***** = **'**relative bioproductivity' indicates by which factor national ecosystems are more productive per hectare than world average

****** = 'global hectares' are hectares with world average biomass productivity

A variety of sub-indicators can be drawn from the national biophysical accounts. For example, they can show how much of the biological capacity (in various ecosystems categories) is used for producing all the goods and services of a country, or how much biological capacity is supplied from local sources and how much is imported or exported. Or they can track how efficiently nations use their resources in order to determine the contribution of technological improvements to mitigate the impact of human activities.

3. Monetary and Biophysical Accounting as Complements

One of the key advantages of monetary accounting is the presumption that 'a dollar is a dollar'—that is, one dollar's worth of two different goods can be presumed to yield the same amount of well-being to the consumer. This does not, however, negate the importance of information on physical quantities. Information on physical scarcity (reserves of minerals for example) is often critical in determining economic efficiency. It is this measure of physical scarcity which permits the owner to maximize the value of a mine. Biophysical information on stock sizes and growth rates for living resources, to give another example, similarly sets the basic conditions for optimal harvest of these resources.

Both accounts provide national averages—but could with more research also generate data about sectors and income groups. While nations are never homogeneous, national average figures as provided by the two accounts offer nevertheless important information for national policy making. For instance, many economic policies, such as monetary and fiscal instruments, social policies such as education, or environmental policies such as pollution standards or resource rents are national in scale.

Biophysical and the monetary accounts are also complementary with regard to scale. Monetary accounts are powerful at the micro level from households up to nations, but have limitations at the global level. At the global level, biophysical measures can better capture trans-boundary effects and the health of the planet as a whole. For instance embedded carbon flows can be factored into a country's biophysical profile. In contrast, global monetary aggregates are often bereft of meaning. To take just one example, global average income per capita is roughly $6000, a figure that masks enormous disparities in income.

Biophysical accounts, in contrast, while useful at the global level, may be less helpful to policy makers at the household level. At the global scale they can address critically important questions. For example, by what amount does global emission of CO_2 exceed the ability of terrestrial and aquatic systems to absorb it? Or, what are the productivity trends of the world's natural capital assets? For most households, however, the income figures of the monetary asset approach will be perceived to be more relevant than numbers on local biomass productivity.

4. Limitations of the Current Accounts

Both frameworks share one significant limitation: the amount of internationally comparable data available at the national level that is reliable and relevant to the accounts. Some data sets are improving, such as land-use and bioproductivity data collected by UN organizations such as the Food and Agriculture Organization. Other areas remain poorly documented. For instance, owing to data limitations the monetary environmental accounts published by the World Bank do not include important resources such as soils, subsoil water, and fisheries, and most local pollutants. Work is underway to improve this situation.

As mentioned, monetary accounts face the further challenge of how to include assets that cannot be reliably priced, and how to reflect critical thresholds of assets where the marginal damage curves may be close to vertical, meaning that substitutes for the asset are of such prohibitive cost as to be nil for all practical purposes. The ozone layer is such an asset.
Biophysical accounts are faced with another set of difficulties. For example, biologically productive land and water accounts are biased towards living resources. Non-renewable inorganic resources (such as ores) are only included in the accounts in so far as their use compromises biocapacity.

Since the biophysical accounts analyzed here avoid exaggerating human impact, human demands on nature that are not sufficiently well documented are excluded. The resulting estimates of excess demand over supply are therefore, conservative. In addition, secondary functions provided by areas already included in the accounts, such as freshwater collection, pollination, or waste absorption of biological waste are not added to the accounts a second time.

Hence, the presented biophysical accounts will be insensitive to a reduction in freshwater use or water pollution.

Furthermore, since biologically productive land and water accounts focus on the regenerative biological capacity, they exclude emissions which nature cannot break down. This makes the accounts insensitive to contamination through heavy metals, radioactive materials and persistent organic compounds, or to irreversible losses of assets such as biodiversity. These aspects need to be tracked separately.

Nevertheless, by exploiting more of the existing data sets, both accounts can become more robust and comprehensive.[xvii]

It is also worth recording that one important area which continues to require further work is the international science which underpins many of the data sets. After all, unlike most economic data, environmental variables are not linear. Thus, scientific study is critically important to advance data sets on sustainability. While the level of scientific knowledge on issues like climate change is very high, establishing thresholds of irreversibility for a whole range global environmental issues remains a pressing priority. Even on an issue like climate science where the level of sci kno has been enhanced in recent years no clear understanding of where the irreversible thresholds lie. It is clear, that such scientific research would help guide and support the further development and improvement of monetary and biophysical accounting.

5. Policy Implications

When used in tandem, the two accounts provide policymakers with a wealth of information. Taken together can provide the *tools for policymakers* by addressing specific concerns relevant to sustainability: how a nation's wealth is changing over time, and what amount of biological capacity it is using. In particular, this tool can assist in identifying the cost of depleting natural capital assets; the cost of demographic growth; the intensity of use of local ecosystems which links directly to pressure on biodiversity; and the distribution of resource use among nations.

In the case of a non-OECD country such as Pakistan, the monetary measurement reveals that the country depletes minerals and energy at 9 dollars a year per Pakistani, and forest harvest exceeds natural growth by a similar amount. CO_2 damages per capita are in the range of other low-income countries. As a result, total depletion and damage more than offset net saving effort. But even without adjusting net savings for natural capital depletion, the per capita loss of wealth due to population growth far exceeds the savings rate. At the same time, a biophysical measurement documents that out of the 0.5 hectares land area per Pakistani, only 0.2 are biologically productive. Due to their intensive use and productive soils, these areas correspond to the biocapacity of 0.7 global hectares. Despite modest consumption levels, the average Pakistani's demand for ecological services of 1.1 global hectares still exceeds the nation's capacity, depending on imports of ecological services and depletion of natural capital stocks. (See Table 3 for similar summary of other countries).

These accounts also offer *a common platform for comparing significant sustainability issues* by tracking them in each accounting system with a common measurement unit. For example in the case of Pakistan, the accounts identify major sustainability concerns: forest overuse, population growth, as well as overall biocapacity constraints in the face of already low levels of resource consumption for average Pakistanis. Using a common framework allows analysts to address issues in concert rather than in isolation, and helps to identify possible synergies and trade-offs.

Table 3: Interpreting selected countries with both accounts.

	Accounting for Nations' Change in Wealth (measured with the monetary accounts)	**Accounting for Nations' Use of Ecological Capacity** (measured with the biophysical natural capital accounts)
Australia	Australia is a major producer of minerals and mineral fuels, reflected in resource depletion of $411 per capita per year. Dispersed population and dependence on coal lead to high CO_2 damages per person. Domestic saving rates per person of over $2100 are relatively low for its income level, while wealth loss owing to population growth is higher than for most other high-income countries.	Australia is endowed with 42 hectares of land per inhabitant, of which 34 are biologically productive. This biocapacity corresponds to merely 9.3 global hectares per Australian, primarily due to water scarcity. In contrast, Australia's vast transportation infrastructure, large share of coal energy, and high consumption of animal products boosts its demand on nature to an equivalent of 8.5 global hectares per Australian, slightly less than the 9.3 global hectares of biocapacity.
Chile	Chile is a leading producer of copper, resulting in an annual $335 depletion per capita. CO_2 damages are typical for their income level. Domestic saving effort is strong but not able to fully compensate for the per capita wealth loss owing to population growth.	Chile controls 5.2 hectares of land and about 5 hectares of productive sea area per citizen. These areas have a biocapacity of 2.0 global hectares per Chilean. This is 2/3 of the biocapacity needed to regenerate what the average Chilean consumes.
Indonesia	Indonesia, a major oil exporter, depletes $61 of mineral and energy resources a year for each of its 200 million inhabitants. Forest use exceeds natural growth at a rate of $6 a year per Indonesian. CO_2 damages are at a similar level. The savings effort is strong, more than offsetting the per capita wealth loss owing to population growth.	The 0.8 hectares of bioproductive land per Indonesian have the capacity of 3.2 global hectares due to the country's high humidity and fertile soils. In contrast, all the resource uses combined correspond to 1.4 global hectares per Indonesian, or less than half of its maximum capacity.
Pakistan	Pakistan depletes minerals and energy at $9 a year per citizen. Forest harvest exceeds natural growth by a similar amount. CO_2 damages per capita are in the range of other low-income countries. Total depletion and damage more than offset net saving effort, but are overshadowed by the loss of per capita wealth owing to population growth.	Out of the 0.5 hectares land area per Pakistani, only 0.2 are biologically productive. Due to their intensive use and productive soils, these areas correspond to the biocapacity of 0.7 global hectares. Despite modest consumption levels, the average Pakistani's demand of 1.1 global hectares still exceeds the nation's capacity, making it dependent on imports of ecological services and depletion of natural capital stocks.
Netherlands	The Netherlands depletes its energy resources at moderate per capita levels, while its CO_2 damages per person are notably lower than those of Australia (partly owing to higher population density). Savings effort is strong, far exceeding the reduction of per capita wealth due to population growth.	Fertile soil, humid climate, and intensive land use boost the actual 0.2 hectares per Dutch person to an equivalent of 2.3 global hectares. Still, the Dutch demand exceeds this biocapacity threefold. The gap between biocapacity and demand is bridged through international trade.

Zimbabwe	Zimbabwe has moderate levels of mineral depletion at $24 per person, and forest harvest (mostly for fuel wood) exceeds natural growth. Total depletion roughly offsets the saving effort, leaving the country substantially poorer in per capita terms once the effect of population growth is included.	Due to water scarcity and poor soils, the 3.5 hectares of land per Zimbabwean is only worth 0.7 global hectares. This is only half of what is necessary to maintain the resource flow of the average Zimbabwean. The difference stems partly from overusing forests.
World	Rough calculations[xviii] suggest that there is a slight net loss of total wealth per person across the globe, amounting to roughly 0.1% of global wealth annually. However, this global average masks the fact that estimated declines in wealth per capita are sizable in roughly 50 countries.	The Earth offers 2.2 (global) hectares of bioproductive space per world citizen. In contrast, the average world citizen demands 2.8 global hectares. The difference indicates liquidation of the world's natural capital (such as forest depletion, fisheries decline, or CO_2 accumulation in the atmosphere).

In addition to providing a country analysis and highlighting critical issues, the two accounts also assist in *identifying policy priorities*. With limited budgets, be they financial or biological, difficult trade-offs are inevitable. Comprehensive frameworks such as the approach presented in this paper help explore the implications of such choices and assist policy makers to prioritize competing needs.

Furthermore, such a complementary approach also supports the *development of policy responses*. The accounts offer platforms for designing policy packages that produce multiple benefits and address the needs of a variety of sectors and the responsibilities of several agencies. They can, for instance assist in the development of environmental policy prescriptions such as improving the pricing of resources and pollutants by capturing, *inter alia*, royalties on mineral and energy extraction, and by enforcing property rights. Such policies improve the efficiency of environmental services[xix] since they reduce incentives to overexploit resources or to pollute indiscriminately.

The natural capital accounts support policy interventions that aim at reducing human use of nature to a level that can be sustained by nature. Since overall use is determined by four factors—population levels, people's consumption patterns, the eco-efficiency with which consumption items are produced, and the robustness of natural capital stocks to withstand degradation—each becomes an area for policy intervention. The tools are the same. For example, policies aimed at reducing carbon intensity include carbon taxation, fuel taxation, trading of carbon emissions and sequestration, and subsidies to technologies that are less carbon-intensive. These policies can complement efforts to improve the monetary accounts of a country, for example where reducing carbon emissions also reduces local air pollution and its associated costs.

In summary, used in tandem, these two measures help track a country's progress toward sustainable development, highlight critical issues and identify policy responses. As a consequence, they not only illuminate the relationship between national and global sustainability, but also help improve policymaking for sustainable development.

Notes and References

[i] Redefining Progress, 1904 Franklin Street 6th floor, Oakland CA 94610, U.S.A., wackernagel@rprogress.org

[ii] Environment Department, The World Bank, 1818 H St. NW, Washington DC 20433, U.S.A., khamilton@worldbank.org

[iii] World Wide Fund for Nature International (WWF), Avenue Mont-Blanc, 1196 Gland, Switzerland, jloh@wwfint.org

[iv] Redefining Progress, 1904 Franklin Street 6th floor, Oakland CA 94610, U.S.A., sayre@rprogress.org

[v] World Commission on Environment and Development (WCED, chaired by Gro Harlem Brundtland), 1987. *Our Common Future*. Oxford University Press, New York.

[vi] P. Dasgupta, and K-G Mäler, 2000, Net National Product, Wealth and Social Well-Being, *Environment and Development Economics* Vol. 5 No.1&2, p69-93.

[vii] David Pearce, Anil Markandya and Edward Barbier, 1989. *Blueprint for a Green Economy*. Earthscan Publications, London.

[viii] Monetary accounts are capable of dealing with many aspects of strong sustainability, provided there is scientific information to support the construction of marginal damage curves. The practical difficulties in establishing these damage curves however, may be more limiting than the theoretical ones. The theoretical limits refer to situations where the loss of welfare is arbitrarily large for a small change in the state of a resource (i.e. where the marginal damage curve is literally vertical). In such cases, the monetary accounting approach breaks down.

[ix] Kirk Hamilton, 2000. *Genuine Savings as a Sustainability Indicator*, World Bank, Washington.

Kirk Hamilton, 2000. *Sustaining Economic Welfare: Estimating Changes in Wealth per Capita*, World Bank, Washington.

[x] See endnote ix.

[xi] Mathis Wackernagel, Larry Onisto, Patricia Bello, Alejandro Callejas Linares, Ina Susana López Falfán, Jesus Méndez García, Ana Isabel Suárez Guerrero and Ma. Guadalupe Suárez Guerrero, “National Natural Capital Accounting with the Ecological Footprint Concept”, *Ecological Economics.* June 1999 Vol.29 No.3, p 375-390.

[xii] E. Matthews, et al., 2000. *The Weight of Nations - Material Outflows from Industrial Economies*, World Resources Institute, Washington D.C.

[xiii] Peter M. Vitousek, Paul R. Ehrlich, Ann H. Ehrlich, and Pamela A. Mateson, 1986. "Human Appropriation of the Products of Photosynthesis." *BioScience*. Vol.34 No.6. p368-373.

[xiv] Parts of this area can be located all over the world. Its size depends not only on the amount of resources used, but also on the efficiency by which the resources are harvested and processed.

[xv] Each global hectare represents the average regenerative capacity of each of the 11.6 billion biologically productive hectares on the planet. These 11.6 billion bioproductive hectares, including 3.2 billion hectares of coastal areas and upwelling zones, host over 90 percent of the world’s bioproductivity. The remaining 39.3 billion hectares that make up the surface of planet Earth—such as Antarctica, the Sahara desert or the deep oceans—provide hardly any biomass production and are host to little life.

[xvi] For more details, consult: World-Wide Fund for Nature International (WWF), UNEP World Conservation Monitoring Centre, Redefining Progress, Center for Sustainability Studies, 2000. *Living Planet Report 2000,* WWF, Gland, Switzerland.

[xvii] Even with presently available data, both accounts have the potential to be fine-tuned and expanded. For example, the monetary asset accounts can include more existing data from valuation research, and could become more comprehensive if more valuation of core natural and social assets become available. Taking advantage of more comprehensive data sets that have recently become available, the biophysical natural capital accounts can become more sensitive to agriculture, fisheries and forestry. They could also improve with further research that would:

- Strengthen the data sets on built-up areas, embodied energy and resources in traded products (particularly as production chains globalize), and embodied energy and resources in services such as tourism;
- Reduce uncertainties about the global carbon cycle and ecosystems productivities,
- Collect more quantitative data on the link between freshwater withdrawal and impact on biocapacity as well as the bioproductivity damage of stratospheric ozone depletion, persistent pollutants, and climate change.

[xviii] For details, see Kirk Hamilton, 2000. *Genuine Savings as a Sustainability Indicator*, World Bank, Washington.
[xix] Efficient pollution policies aim at investing in pollution abatement up to the point where the marginal cost of abatement begins to exceed the marginal cost of pollution damage.