A Natural Resource-Systems approach: Targeting the Ecological Transition at the Regional Scale

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1. Introduction[1]

Human history can be mirrored in a geo-history of natural resources (Dasgupta, 1982 and 2010). Humans, by over-exploiting resources ("forcing"), have produced extensive land use changes and have altered complex food webs, ecosystems, and habitats with as a consequence systematic natural biocapacity erosion, biodiversity loss, energy crises, pollution, climate deregulation (Pauly *et al*, 1998, Griffon, 2006, Ellis *et al*, 2010; Foley *et al*,

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2005 and 2011; Lotze *et al*, 2011; Dittrich *et al*, 2012). In other terms, a global resources "rush" has led to chronic socio-ecosystemic deficits, thus creating the conditions for local and global state shifts within the biosphere and / or society (Ravillon *et al*, 2007; Ferone, 2008; Barnosky *et al*, 2012; Running, 2012).

Therefore, research must serve to increase human understanding of those resources and how best to use them for the public good.

The question is how to approach the problem in order to integrate the economy into the cycles and functions of the biosphere, while providing society-wide access to vital resources and services (Costanza 2004 and 2010; Brown, 2006). According to the SCAR 3rd foresight (Freibauer *et al*, 2011) "*the increasing scarcity of natural resources and destabilization of environmental systems represent a real threat not only to future food supplies, but also to global stability and prosperity, as it can aggravate poverty, disturb international trade, finance and investment, and destabilise governments*". In addition, Dasgupta (2010) considers that "*individuals and communities over-exploit natural capital, meaning that the ecological services are subsidized. Social norms and legal rules are at the root of the system*".

We therefore argue that natural resources as a whole (human resources included) represent the central issue in sustainable development and the ecological transition. An integrated resource-driven approach and the reframing of the geopolitics of natural resources appear as pre-requisites in addressing more coherently and in a context-specific manner most, if not all, of the present time challenges: greenhouse gas emissions, climate change, biodiversity, food security, as well as energy and other poorly interconnected resources (water-soil-air, food-health-education-environment etc) (Negrutiu, 2011; also see Scheffer *et al*, 2009; Deffuant *et al*, 2012; Dittrich *et al*, 2012).

Developing a natural resource-systems approach is expected to provide a proper conceptual frame and integrative tools and methods from diverse disciplines (such as natural sciences, economy-finance, social and legal studies) for (1) the maintaining of a strong life-supporting capacity of the natural capital and (2) the sustainable/equitable production, access, use, distribution, and circulation of natural resources according to territorial natural resources capacities / specificities and governance skills. This implies analysing the socio-economic / financial / normative-legal contexts, policy instruments, and institutions characterizing the considered territorial entity (a region, a country, the EU), while jointly addressing the issues of (and measuring very precisely) the present ecological deficits (Thara Srinivasan *et al*, 2008), the internalization of socio-environmental costs, as well as controversial questions such as carrying capacity and economic competition.

Before exploring these aspects, a broad-brush analysis of the resource problematic is presented.

2. Current Understanding of the Natural Resources Problematic

The natural capital can be defined as a mesh of resources (Dasgupta, 2010). Resources are a socio-cultural construction: the culture, the law, and the technology define what is (or could be) a resource. Their perception through life-styles and technological change is constantly evolving. Today, the political statement that current economies can grow indefinitely in a world with finite resources is a gamble.

Resources remain elusive as both identified and measured, but also undiscovered and inferred resources feed systematic controversies. Reserves, by contrast, are identified resources that meet extraction and production criteria in terms of investment and profitability

(US Geological Survey glossary). Considerations such as exploration versus production, prices versus costs, and the accuracy and veracity of reporting by companies and countries all have impacts on resources information (Aschzet *et al*, 2011). They also affect the science devoted to them, with technological advances continuously modifying the resource to reserve balance.

An increasing number of compounds from biotic and non-biotic, renewable and non-renewable resources are being transformed according to inferred needs into a diverse range of functional materials. Not surprisingly, the resource issue is largely restricted to its economic and market logic, natural resources being merely considered as fluxes of values and exploited with no consideration of environmental or social costs (EEA report, 5/2011). Of note, the exploitation of non-renewable resources is dealt with in terms of potential substitutable materials, while renewable resources are managed as available stocks. The demographic and market pressures, and the global natural resources "rush" have led to chronic socio-ecosystemic deficits / debts (Weber, 2011; E-risk report 2012), mirrored by food-health-environment-poverty/culture disequilibria (Meadows *et al*, 2005; Brown, 2006). Taken together, such considerations have prompted research on the Common-Pool Resources concept (Dasgupta, 1982; Ostrom *et al*, 2002; Baron *et al*, 2011). They may further stimulate work revisiting the renewable resources concept in regard to questions such as: how pertinent the term "renewable" is today for resources which are expected to maintain their regeneration potential (biocapacity) and which in reality undergo extensive degradation / deterioration, and fast or frequent devaluation.

2.1 Non-renewable Resources: Differential Scarcity and Material Intensity

Given the volumes physically available in the Earth crust and oceans, and the potential to recycle, there is no theoretical constraint for any of the chemicals / minerals under consideration. The Earth crust is approx 30 km thick, but most explorations rarely go deeper than 1-2,000 meters deep (Aschzet *et al*, 2011).

During 1980 – 2005 the resource extraction intensity has been increased by 160% with material intensity being reduced by 25%. Since the population growth averaged 45% during the same time period, the decoupling of economic growth from natural resources use has not been achieved yet (UNEP report 2011, http://www.unep.org/greeneconomy).

Furthermore, there is the tightly linked soil fertility and water shortages problem (Griffon, 2006; Foley *et al* 2005; Hoekstra and Mekonen, 2011). While land pressure for bio-based products (biofuels and a variety of bio-materials) is growing in competition with food production needs, severe water shortfalls are predicted for two-thirds of countries (http://water.worldbank.org/node/84122; http://www.weforum.org/issues/water/index.html).

"Energy is the one and only real limiting factor in the long run, because given enough energy there will always be enough natural non-energy resources extractable from the crust of the Earth" (Neumayer, 2000). Energy consumption is increasing steadily, with electricity as the dominant form. Today, over 60 metallic elements are involved in energy pathways, so their availability, functionality, substitutability and recyclability are of concern in decision-making (Aschzet *et al*, 2011). The environmental and human health performance of such materials and the generated waste are crucial societal issues in terms of dissipation and dispersion, recycling capacity etc and significantly can impact supply and demand.

2.2 Renewable but Exhaustible Biological Resources

The environmental considerations and the expected relative scarcity of non-renewable reserve stocks set the scene for alternative solutions based on renewable natural resources (Barbault and Weber, 2009; Alternatives Internationales, 2012, Griffon, 2013). The challenge is huge as the weight ratio of non-renewable to renewable resource intake is 50 :1, raising concerns about the capacity of the "*exclusive renewable energies options to offer but simple material-based life style societies with high level of self-sufficiency*" (Neumayer, 2011 and refs therein; Smith *et al*, 2012). The main question so far is not decarbonating the economy, but how to manage the transition from a fossil carbon to a green carbon economy.

Let's have a closer look. The green carbon economy is totally dependent on biomass generated as Net Primary Production (NPP), which subtends the Carbon cycle of the biosphere. The state and dynamics of NPP (Running, 2012) support most of the basic functions and services of ecosystems and habitats, the various food webs (i.e species diversity / biodiversity) and humans' ecological footprint (Pauly *et al*, 1998; Living Planet report 2012).

The contribution of biomass as a multi-use resource for human needs is rapidly increasing: from a global NPP of 536 billion tons, 7 billion humans co-opt 38%, with a theoretical 10% available for additional human use with respect to non-harvestable parts required for biosphere equilibria (Running, 2012). Further forcing on NPP through today´s food production systems compromise the capacity of Earth to produce food in the future (Godfray *et al*, 2010; Foley *et al*, 2011; Beddington, 2011).

2.3 The Human Resource

Humans are a paradoxical resource as both diversified consumers of exhaustible resources and creators of unlimited ones: knowledge and personal data are continuously and fast growing raw materials.

The projected increase in human population to 8 billion in the next decade and improving living standards are expected to increase the demand for food, water, and energy by approx. 35, 40, and 50% respectively by 2030 (Global Trends 2030, www.dni.gov/nic/globaltrends). The controversial demographic and related carrying capacity issues (Agenda 21, 1992; Turchin, 2009; Engelman, 2011) require therefore an increased involvement of the scientific community. For example, agricultural expansion beyond 50% of available land / ecosystems is considered as a critical threshold (Barnoski *et al*, 2012; also see Good and Beatty, 2011).

2.4 Unequal Distribution of and Access to Resources: the "Boomerang Effect"

The unequal (quantity and quality) distribution of resources has generated an annuity system, on which, in turn, an ambiguous relationship with economic development has been created and constitutes a permanent source of geo-political conflicts. A contrasting picture prevails.

(1) Financial, but also non-financial accounting systems are presently considered worldwide in sovereign credit assessments. The "E-RISC report" describes methods and metrics for quantifying natural resources, renewable resources in particular, and the corresponding environmental risks. The assessment is particularly critical for countries that "*depend, in net terms, on levels of renewable resources and services beyond what their own ecosystems can provide*". Obviously, this is the situation for most countries today. The E-RISC approach is a major step forward in putting upfront the concept of ecological debts as a risk factor. There is a need for a real systemic and global accounting for the natural capital (as much as economic accounts are systemic), including natural resources production, supply, use, consumption, accumulation, and trade, with corresponding remunerations, profits, taxes and subsidies, financial flows and assets, and debts originating from the entire process (i.e., a robust statistical base to support ecosystemic debts calculation).

(2) Most States are not capable of adapting their resources to the basic needs of their populations (FAO, 2009; Mazoyer *et al*, 2008) for reasons that are strongly linked with the international laws pertaining to international investments and trade, and with the regulations of the World Trade Organisation (Collart Dutilleul, 2012 a and b; Honet & Negrutiu, 2012). Other States develop strategies for the more sustainable management of their natural capital. A useful study case is the Management Resources Act, 1991 of the New Zealand that restates and reforms the law relating to the use of land, air, and water (see ***Section 5.2***).

3. Why the Regional Scale Matters?

Natural resources at the regional level have economic, financial, environmental, and socio-cultural meaning at the same time. Therefore they are likely to "speak" more directly to society and individuals in terms of stock, flux, and footprint, but also in terms of responsible attitudes and actions through social networks and links. The temporal and spatial representations of the state and dynamics of regional resources, such as ecological deficit and debt (not erasable, contrary to financial debts by contractual agreement or government bailout), carrying capacity, internalization of socio-environmental costs, socio-economic competition, etc are likely to become politically and society-wise more readily meaningful than equivalent global figures. The socio-ecosystemic virtues of circular economy systems make sense at local-to-regional territorial scales. Therefore, the coordinated and integrated management of natural resources at the regional scale is likely to become an important political issue in the short run. To that end, enabling regional monitoring and accounting will allow devising optimized solutions adapted to local specifics (Seitzinger *et al*, 2012; Griffon 2013) by engaging various stakeholders, economic actors, and policy-makers . This should contribute to enhancing the responsibility levels in decision-making and in society at large, therefore facilitating the ecological transition process.

Converging elements indicate that the decision / action power is emerging at the regional scale. For example, the EU has operationally defined a regional grid of policies across the continent for a variety of developmental strategies, objectives, and projects (European Regional Development Fund). Furthermore, at the national level, the French law dealing with the modernization of agriculture and fisheries (2010) and, more generally, the emerging territorial sustainable development policies, have created in each region overlapping bodies and /or programs:

(1) A "Plan Régional de l'Agriculture Durable" (PRAD – regional sustainable agriculture plan) for a seven-year period. The PRAD includes the implementation of indicators and assessment criteria (http://draaf.rhône-alpes.agriculture.gouv.fr/Plan-regional-de-l-agriculture);

(2) A "Plan régional pour l'agriculture et le développement rural" (PRADR – regional plan for agriculture and rural development) was voted in 2010 and includes, for example, the territorialization of action by the Region through strategic rural development projects (PSADER);

(3) The CESER (the economic, social and environmental regional council) produces periodic assessments at the cross-road of economic, social, and environmental questions;

(4) The PSDR approach ("Pour et Sur le Développement Rural"), an INRA-IRSTEA research program on regional rural development has been operational for a dozen or so years (http://www6.versailles-grignon.inra.fr/sadapt/Equipe-Proximites/Les-programmes-PSDR). Among the PSDR3 key-recommendations, the preservation and valorisation of territorial resources and regional specificities stands out as a program on its own.

Last but not least, information technology is fostering big data systems. Data storage and processing power, together with extensive networking, is providing global access and pervasive services (Global Trends 2030), making regional capacities in decision-making feasible and necessary. The EU has established an in-house expertise on big data production within a network of institutes coordinated by the Joint Research Centre and the European Environment Agency (http://ec.europa.eu/dgs/jrc/index.cfm), with clear-cut objectives on a series of environmental and ecosystem indicators.

4. The Resource-Systems Approach

Specific natural resources (water, soil / land use, food-biomass-agriculture, bio-energy, etc) have recently been thoroughly analyzed at planetary scale (Foley et al, 2005 and 2011; Ramankuty et al, 2008; Ellis et al, 2010; Hookstra and Mekonen, 2011; Smith et al, 2012). This patchy knowledge gives an idea of the immensity of the task at global level. Three components are considered in building the systems approach, namely the conceptual level (identified as the “missing link”), the methodological and governance levels to be calibrated at the regional scale to start with (identified as the “missing tools)”. The overall expected result is a continuously upgraded natural resources monitoring, accounting, and diagnosis as an aid to decision-making allowing the discrimination of facts and trends from ideological considerations. These are basic prerequisites for a coherent and effective ecological transition process.

4.1 The Conceptual Level – Reframing the Natural Resources

The conceptual level considers the necessity to entirely reframe the field of natural resources and public goods, starting with clarifying the terminology relative to natural resources and related terms. At the same time, it is important to proceed towards an interdisciplinary academic appropriation of the natural resources problematic as a whole (Negrutiu, 2011; ***Figure 1***) through questions such as “How to coherently define, address, and manage human fundamental needs and rights (food-health-environment-education/culture), the common / public goods issues and the competition / innovation syndromes?”, or “Why are humans primarily resource-minded and wrongly resource-framed?”. Setting up a renewed experimental framework should encompass, among others:

(1) Surveys, questioning the perception and relationship between humans (individually and collectively) and resources (natural, human, economic, institutional or cognitive);

(2) Inventories and critical analysis of institutions, programs, and corporate bodies that have recognized expertise on natural resources, allowing the identification of the main gaps and overlaps in the field. For example, the World Resources Forum (WRF) is the science-based platform for sharing knowledge about the “*economic, political, social and environmental implications of global resource use*; (http://www.worldresourcesforum.org/).

(3) Studies on the geo-history and geo-politics of functional and cultural materials, including work on questions such as functional materials for agriculture, industry, services, e-economy, but also innovation / technology and resources typology and topology across time (politics, conflicts, diplomacy, and governance; Gabriel-Oyhamburu, 2010; Goetschel and Péclard, 2006) and the Great Acceleration (Steffen, *et al*, 2007).

(4) Translate the resources problematic as a whole by systematically and globally linking food-health-education/culture-environment, a fundamental equity problem of present-time generations. Such an “equation” has largely been neglected so far, despite ongoing efforts through the Millenium Development Goals (goals 1-3 and 5-8; http://en.wikipedia.org/wiki/Millennium_Development_Goals).

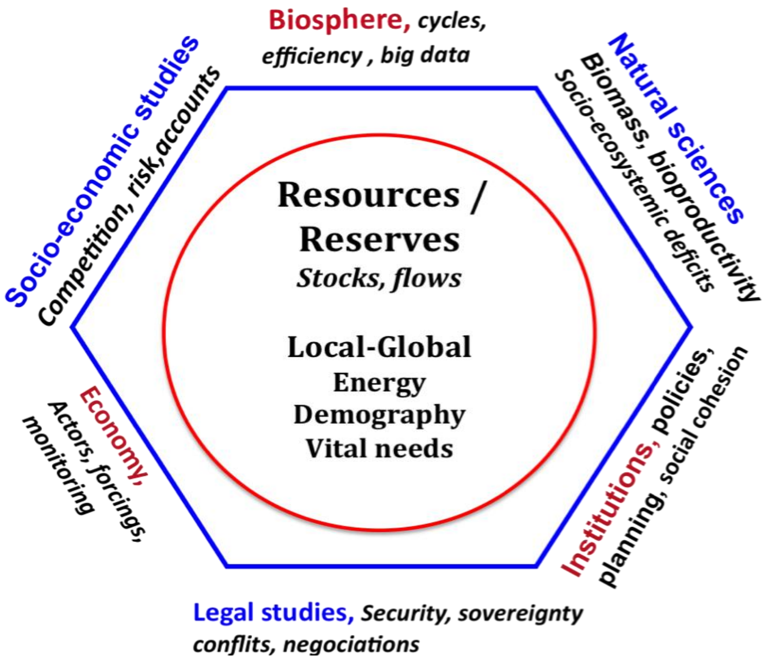

Figure 1. The resource-systems matrix of development and ecological transition. Reframing the conceptual and operational field of natural resources makes it possible to establish more coherent and effective links between vital needs and otherwise unrelated or poorly related factors/components and the corresponding risks: food-health-education/culture, environment, energy, climate change, biodiversity, future generations and so on. This requires deep interdisciplinarity across fields encompassing legal and socio-economic studies, and life-sciences.

4.2 The Methodological Approach – Integrating the Big Data Revolution

The methodological approach aims at adapting and/or developing (real-time) monitoring tools and methods at the regional scale in order to establish, understand, and model the state, dynamics, and accounting of physical natural resources as a whole according to territorial natural resources capacities / specificities and governance skills. Modelling of natural resources requires the production, access, and circulation of data sources and coordinated interdisciplinary work (also see Purves *et al*, 2013 on climate change and "all life" modelling and ecological transition timing at http://www.neweconomics.org/publications/greattransition). In parallel, the financial, socio-economic, legal, normative, and political contexts, instruments, institutions, and skills need to be analysed and articulated according to trade-offs between environmental, legal, economic, social, and cultural outcomes.

These aspects are presented and discussed below and address the renewable resources in the first place.

5. Cross-talk between Natural Sciences and Social Studies

The systems approach to the natural capital and ecological transition ***(Figure1)*** requires coherent and concerted thinking and action across disciplines, in particular in economic, legal, social, and life-sciences. We identify below several key questions that require a consistent cross-talk between these disciplines in the first place.

5.1 Resources Economy and Environmental Economy Studies

The economy is not yet accountable for Nature's degradation (Dasgupta, 2010; Weber, 2007 and 2011; Dittrich *et al*, 2012). National, regional or local governments or companies do not keep ecological balance sheets. Consuming ecosystem capital (i.e. loss of ecosystem capability) without accounting for it is equivalent to creating ecological debts that are transmitted to others, to our present and future generations or to countries from which imported products are produced under unsustainable conditions (Dittrich *et al*, 2012).

The "E-Risk" approach has been described in ***Section 2.4***, but the ecological footprint indicator has recently been questioned (Blomqvist *et al*, 2013). Among the alternatives, we analyze here the "ecosystem capital simplified accounts" that are currently being implemented in Europe by the European Environment Agency (Weber, 2011). Their objective is to measure the ecosystem resources that are accessible without degradation, their intensity of use, and the change in the capability of ecosystems to deliver their services over time.

The state of the ecosystem can be assessed without going into the detail of the services provided. Valuation is limited to critical flows of services on the one hand, and to ecosystem change (no need to value the ecosystems themselves) on the other hand, for which estimations can be based on the observable costs of management and restoration/rehabilitation actions of land and soil, forestry, water, rivers, and catchments or even biodiversity.

To territorial debt, should be added the consumption of non-paid ecosystem capital that is embedded in international transactions. The ecological debts (and symmetrically credits when improvements occur) can be subsequently incorporated into portfolios of financial instruments organized in ecological balance sheets.

Presently such accounts increasingly benefit from big data systems allowing the continuous monitoring of state change and variation through Earth monitoring by satellite programs, *in situ* monitoring systems, and fast processing of socio-economic statistics. In other words, (near) real-time monitoring and accounting tools are becoming accessible at various territorial scales.

The "ecosystem capacity of production and servicing" in a given territory is measured with the aid of an ecosystem capability accounting tool. This is based on a composite index measuring changes in available resources, the intensity of their use for private and public benefits, and direct and indirect qualitative impacts (pollution, landscape integrity and biodiversity).

The first step consists in establishing the land-cover stocks and flows (i.e. the territorial land repertoire as gross and net changes, Weber, 2007). On that land matrix, the productivity capacity of biological resources (with biomass as a major concern; de Bossoreille de Ribou *et al*, 2013), but also water and soil productivity and footprints, are critical and can now be monitored (Ellis *et al*, 2010, Hoekstra and Mekonen, 2011; Benwart, 2011, Smith *et al*, 2012). In our hands, such indicators inform the Landscape Ecosystem Potential and integrate qualitative variables reflecting (agro)ecosystem health (Weber, 2011). The geographic data management is required firstly to analyse short-term degradation of the socio-ecosystems. This is important because the extent to which we manage the productive potential of natural resources will determine the range of options and solutions we can count on in the (near) future.

A complete grid of these factors and their equivalence with economic units is given in **Figure 2**. The calculations in ecosystem potential (or capability) unit-equivalent (EPUE or ECU) are described in the Technical Report 13/2011 of the European Environment Agency and in a spreadsheet with mock-up numbers (downloaded from http://projects.eionet.

europa.eu/leac/library/e_c_a_fast_track_provisional_repository/background_documents/seca_ecu_model-annex_tables_to_simplifed_framework). It includes detailed tables as well as charts and a small tutorial showing how to calculate ECU values for a given ecosystem.

This approach has manifold implications because it:

1. Reveals the dual aspect of the natural capital, based on the fact that the ecosystem assets are both suppliers of goods used for final consumption and a capital that reproduces such goods and can be degraded in case of excessive exploitation;

2. Allows translation of debt and risk concepts into versatile metrics allowing in turn to operate with the aid of restoration / compensation equivalent values;

3. Identifies the causes of natural capital degradation (stress factors) and the corresponding liabilities of economic sectors and agents or of the community itself (e.g. in case of land planning impacts);

4. Demonstrates the need for high quality of and access to various public data sources in order to foster scientifically sound and verifiable measurements prone in turn to support effective policy measures;

5. Identifies improvements needed in public and private accounting standards for measuring the management behaviour of and liability to the natural capital.

The results can be compared to other available tools that measure the human impact on the natural capital, namely:

1. Ecological Footprint and regional biocapacity / bioproductivity as described in the "E-risk" protocol (E-Risk report 2012) and protocols and indicators according to Sutton and Costanza, (2002);

2. HANPP (Human Appropriation of Net Primary Productivity) measuring the primary production appropriated by humans (Haberl *et al*, 2007);

3. Resource-use indicators integrating materials, water, land area, and GHG emissions (Dittrich *et al*, 2012).

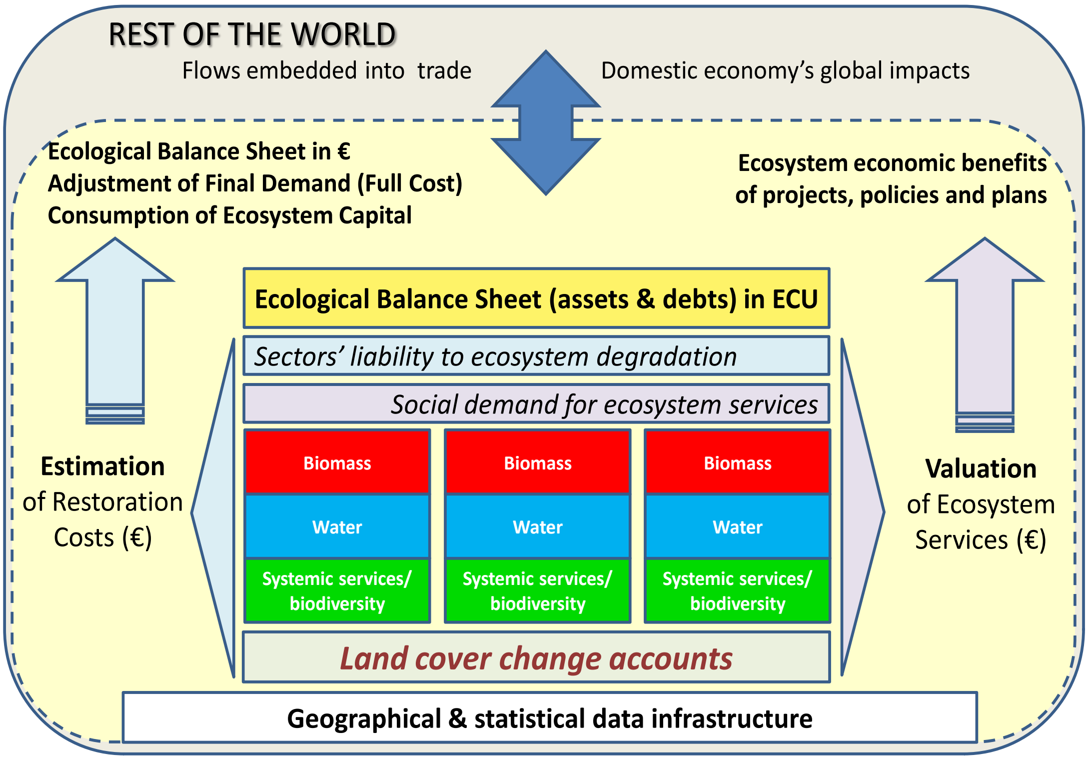

Figure 2. The overall framework of ecosystem capital accounts and applications by ecosystems, sectors, or regions. The Ecosystem Capital Account (ECA) framework is based on the measurement of ecosystems performance, enhancement or degradation of their capacity of delivering services in a perpetual way. Each ecosystem is recorded considering firstly three quantitative balances of biomass, water, and system-based functional services. These quantitative accounts pay attention to the measurement of an effectively accessible resource (instead of the theoretically available one) considering quality, timeliness, and randomness issues. In addition to quantitative measurements, the ECA framework includes qualitative indexes in order to reflect intrinsic ecosystem values, such as the stability of carbon pools (linked to the age of the systems), their intoxication, and dependency on artificial inputs (labour, energy, chemical, irrigation water…), their integrity and biodiversity. A composite index integrates these quantitative and qualitative indexes into a measurement of the ecosystem capital capability – so-called Ecosystem Capability Unit (ECU). This unit-equivalent can be used for any ecosystem, at any scale by central, regional or local governments as well as by companies. It can measure stores of ecological values and their change resulting from modification of any of the three basis components. It can be used in the context of mitigation systems and support compensations and to measure ecosystem capital consumption embedded into international trade. These are the characteristics of a currency: universal equivalent, usable for storage of value and in exchanges. Accounts in ECU are finally integrated into a balance sheet, as are the economic accounts. The second dimension of ECA is valuation, which is made easier by the existence of well structured accounts in physical units. This approach is in line with the TEEB stepwise approach to valuation (http://www.cbd.int/doc/meetings/im/rwim-wafr-01/other/rwim-wafr-01-teeb-en.pdf).

5.2 Legal Studies and Natural Resources Management

Such studies are particularly necessary for both paving the road of the ecological transition process and identifying the corresponding limits, obstacles or breaks (such as transparency of data and information, dissemination of results and choice of solutions, security / sovereignty issues, human and property rights, legislation incompatibilities, etc). Legal and social considerations on the accelerated erosion of physical natural resources can reveal risk factors of induced social shrinkage. For instance, a transition process should jointly address the issues of vital needs and public goods by linking food, health, education, and environmental factors in both time (present and future generations) and space (local versus global). Their regional security, according to the territorial potential and an optimized resources efficiency, requires adaptive governance and persistent good practices (see for ex. the 2004 Environmental Liability Directive 2004/35/CE).

Legal studies are also conducted to evaluate the conditions of an equilibrium of local versus global-level legal systems as a sort of limit to globalization, i.e. to what extent a region can develop its own policies relative to natural resources security and public goods without infringing upon the international rules (intellectual property rights, WTO laws, international investment law, etc). A relevant example is the marine resource (food, energy, minerals, etc) and the contrasting to controversial legal status of sea zones, protected areas, etc (Jarmache, 2013).

We analyse below the 1991 Resource Management Act of New Zealand that restates and reforms the law relating to the use of land, air, and water (also see Ostrom *et al*, 2002; Thoyer, 2006, Baron *et al*, 2011, Levebvre *et al*, 2012).

5.2.1 The Resource Management Act (RMA) - a significant reform in New Zealand's environmental law

The RMA constitutes a major effort in order to bring together more than 50 disparate and punctual environmental laws (mainly dedicated to sector-based subjects) under one single and transversal text. According to the Parliamentary Commissioner for the Environment, RMA's "*passage into law was preceded by a well funded, intensive and extensive process, called the Resource Management Law Reform (RMLR), that was tasked to explore new approaches to resource management, influenced by concepts of sustainability as well as by ideas of efficiency and accountability*" (Parliamentary Commissioner for the Environment, 2002, p. 138.).

The RMA's purpose "*is to promote the sustainable management of natural and physical resources*" (Section 5). This act addresses jointly several environmental matters (Sections 6 and 7). It promotes a model of development that takes into account a range of aspects, such as the recognition of the intrinsic values of ecosystems, life dependence on natural resources and the maintenance and enhancement of the quality of the environment, the necessity to preserve them for the protection of historic heritage and customary rights, but also for future generations. An additional main objective is the evaluation of the impacts of human activities on the environment, in order to avoid, remediate, or mitigate any adverse effects of activities on the environment.

5.2.2 The RMA: reframing the environmental decision process

The general structure of the environmental decisions process is built on a hierarchy of documents that must be considered when deciding to grant or not a resource consent (Section 104): at the top, "national environmental standards", "national policy statements", and the "New Zealand coastal policy statements" (Sections 43, 45 and 56); in the middle, "regional policy statements" and "regional plans" (Sections 59 and 63); and finally, at the bottom, "district plans" (Section 72). The documents at the middle should be consistent with those at the top, and documents at the bottom must be consistent both with documents at the top and documents in the middle.

From an institutional point of view, the RMA involves various sectors of society. For example, the granting of resource consents requires the consultation of various governmental, regional, and local agencies. This situation resulted in a break-up of participants in the decision process and in the increase of administrative departments concerned. Consequently, the decision process planned in the RMA has affected the uniformity of local decisions. This was particularly blatant in cases in which it was necessary to integrate economic and social factors taking into consideration the regional or local context, since every agency could have a different approach on common subjects.

The RMA is considered as an "information intensive" statute (Parliamentary Commissioner for the Environment, 2002, p. 156.), i.e. it requires data about natural resources and, more widely the environment. To this end, Section 35 asks local authorities to gather information in relation to the state of the environment, effectiveness of policy statements, and plans and resource consents.

According to New Zealand's Ministry for the environment (Ministry for the Environment, 2011, p. 6), a "*credible state of the environment monitoring and reporting is critical to good decision-making. In order to build a reliable and accurate national picture of New Zealand's natural capital, we need a regular and independent state of the environment reporting system which is underpinned by high quality, consistent statistics that conform to standards for official statistics*".

5.2.3 Limitations and gaps of the RMA - a narrower concept of sustainable development

If this conception of "sustainable management" and the sustainability discourse of the 90's have been, in some way, a success story, today's doctrine and politics underline that "*New Zealand has not followed an overall strategic approach, but taken a variety of steps related to sustainable development*" (Bosselmann, 2007, p. 1). These steps include various legal reforms (see the Environment Court Act 1996 and the Local Government Act 2002) and policy documents such as the "Environment Strategy 2010" (1995) or the "Government's approach to sustainable development" in 2002. But "*there is no coherent approach behind these initiatives as they vary in purpose, content and scope. Moreover, they do not include any of the features typical of a National Sustainable Development Strategy, such as an analysis of existing practices, public debate, capacity-building, monitoring and an independent advisory body*" (K. Bosselmann, 2007, p. 2). For this reason, doctrine and politicians wonder which concept of "sustainable development" is being pursued, what it clearly means, and how it relates to current practices (see Paper to the Cabinet Policy Committee, 2001; the report The Government's Approach to Sustainable Development, 2002; the report of the Parliamentary Commissioner for the Environment, 2002).

The exact contribution of the RMA to sustainable management of natural resources in New Zealand is difficult to evaluate because of the absence of dedicated assessment tools ever since the RMA was enacted. Many years after the enactment of the RMA, the major efforts of advised commentators have pointed to the interpretation of the Act's provisions. Few efforts have been made to evaluate the effectiveness of these provisions and their outcomes, as well as to establish an advisory body responsible for overseeing and coordinating the decision process meant to achieve local as well as national goals.

Furthermore, considering difficulties of the local authorities in assuming environmental reporting functions, the national government proposed a series of environmental performance indicators for air, marine, climate change, land, waste, transport, pest and diseases, energy, biodiversity, etc. However, not all of them have been completed or used. Moreover, the costs of obtaining information and the availability of environmental information (there are disparities of criteria and indices because there is no requirement in the RMA for local authorities to supply standardised data to the Ministry's environmental statistics programme (2011, p.15) constitute two key problems in the implementation of the RMA provisions.

Another difficulty is that local reports tend to exclude social and economic dimensions and some do not reflect the RMA's emphasis on natural resources management. Moreover, some issues (e.g. resource use efficiency) are not addressed by the RMA. Finally, reactions to the effectiveness of RMA over the last ten years point to the lack of additional tools, and in particular, of economic instruments (such as incentives, funds, and green taxes). As a consequence, admitting a narrow interpretation of the RMA scope, "*many local authorities deliberately operated a separation between social/economic planning and environmental planning. Doctrine and politics are still debating over the meaning of sustainable management*".

5.2.4 Green indicators and the effectiveness of the RMA legislation

In the report "Creating our future: sustainable development for New Zealand", the Parliamentary Commissioner for Environment paints a broad-brush picture of sustainable indicators as part of an upcoming national strategy: "*The 'green' GDP and a proposed 'composite index of sustainable development" were considered the ones that most adequately reflected all aspects of sustainable development. The Ecological Footprint and the Human Development Index were rated the highest in terms of practicalities (data availability, cost, long-term data available), but had a number of weaknesses*" (p. 106). How can a country develop useful indicators that, reflecting the state of natural resources, will influence decision-making? The Ministry for the Environment of New Zealand has been working for some time on a set of Environmental Performance Indicators to measure changes caused by various pressures on environment and guide decisions on environmental problems. However, this set of indicators remains incomplete (Patterson, 2002).

5.3 Reframing the Legal System(s) of Natural Resources

The rather unique case of New Zealand illustrates the fact that from the legal point of view it is difficult today to devise coherent, long-term policies on the global management of natural resources. Thinking about France, for example, we are witnessing a segmentation of powers (also see ***Section 3***) when actually coordination is necessary to ensure such management:

- the state is in charge of the territorial administration; it adopts rules of international law relative to economic activities, protection of the environment, etc;

- the Region is in charge of developing economic activities;

- the Department puts in practice agricultural policies and covers the field of agriculture and farmers;

- the Commune manages land administration and establishes its own land use plans over its entire territory;

- private owners have full power to manage the natural resources they own; this gives them property rights, which is a human right protected by the Constitution.

From the point of view of Law, it is therefore necessary to rethink the legal and political organisation of powers in order to define where and how to place the "centre of gravity" in managing natural resources. Our working hypothesis is that the regional level could be an ideal centre (also see ***Section 3***). However, the regional political level across the world is characterized by a diversity of statutes. This diversity, associated with a variety of resource management systems, deserves further studies on how particular types of regional political organization should best be adapted for a more efficient management of natural resources.

An additional concern is the situation of the States in regard to the rules of international trade and international investment. International law favours the freedom of choice of productions, the free flow of investments, and the free movement of goods by empowering private operators. These rules deprive governments of the ability to adjust local, regional or national production (what is produced from natural resources) to meet the population needs, but are also preventing States from opposing those rules in a binding and significant way.

To address these problems, we must imagine new legal tools for natural resource management upstream of the production stage. Overcoming the limits posed by international trade laws implies conceiving reasonable modifications of the latter, in order to give States the capacity to develop (sovereign) public policies addressing the basic needs of the population.

6. Conclusions

The above considerations can be summarized as follows:

1. The increasing overexploitation of natural resources, the 8 billion demographic challenge in terms of unsustainable life styles versus persistent poverty within the next decade, and the fast contraction of ecosystems' resilience are expected to produce undesired state shifts in the biosphere and society;

2. Such shifts are setting limits to growth and will determine the range of future options and solutions for developmental policies. It is therefore extremely urgent to address the resources problematic via a systems approach mobilizing deep-interdisciplinary expertise;

3. Natural capital monitoring and accounting, and non-financial reporting will become the norm in the very near future and require continuous development and refinement of dedicated tools by the scientific community;

4. Natural resources management as a whole is a main driver of sustainable developmental policies and calibrated territorial ecological transitions;

5. The objective is to globally achieve optimized resources efficiency according to the territorial potential and to ensure their regional security through adaptive and responsible governance and persistent good practices;

6. Regions and countries with diverse and resilient socio-ecosystemic conditions and policies are going to be at a strong competitive advantage over the medium- to long-term;

7. In spite of the difficulties noted, the Resources Management Act of the New Zealand constitutes a major advance in environmental law that clearly revolutionised the approach to natural resources, as well as the process that guides environmental decisions. The approach deserves a more general consideration and developments in the international community as a whole.

8. Our analysis sets the stage for a systems approach to natural resources through (real-time) big data exploitation in combination with socio-economic and legal instruments. Such tools and instruments will generate more coherent legal, social, economic and ecosystemic frameworks that can secure a system of sustainable food, health, education, and

environment for the society at large. A must if we want to tackle the 8 billion challenge through local development.

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